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ABSTRACT

GRADES OR AGES: Inservice course for secondary teachers. SUBJECT MATTER: Earth science. ORGANIZATION AND PHYSICAL APPEARANCE: The guide is intended for use with a 32-program television course for teachers, with material intended to be used in the classroom. The introductory material explains the rationale of the course and includes the transmission schedule and bibliography. Each lesson section is divided into four segments--objectives, a list of references, suggested activities, and a content outline of the material. The guide is offset printed and is in a looseleaf binder. OBJECTIVES AND ACTIVITIES: The objectives are listed at the beginning of each lesson. Suggested activities are included in each lesson and are intended to provide examples of student investigation, demonstrations, or activities which will demonstrate a particular concept. INSTRUCTIONAL MATERIALS: References to relevant printed material are given in each lesson, and other materials are also referred to in the text. STUDENT ASSESSMENT: No provision is made for evaluation. (MBM)

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EARTH SCIENCE

IN-SERVICE TELEVISION PROGRAM

NORTH CAROLINA DEPARTMENT OF PUBLIC INSTRUCTION / RALEIGH

PREPARED AND PRESENTED BY

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DIVISION OF SCIENCE EDUCATION

SP007022

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INTRODUCTION

The purpose of this publication is to provide a guide and reference for you, the teacher, taking this in-service television course. The course is organized into thirty-two programs, each thirty minutes long, which will be broadcast following the schedule on page 3. This guide is organized in a similar manner. There are thirty-two lessons, each corresponding to a program. Each lesson section is divided into four segments. The first segment states the objectives or goals which the lesson hopes to accomplish. The second is a list of references, and the third is a group of suggested activities. The fourth is a content outline of the material to be discussed in that lesson.

The Reference Section:

Each lesson is referenced in several texts. Whenever possible, all three state-adopted texts are cited first and in the following order:

1. Hibbs, Albert R. and Albert F. Eiss. THE EARTH-SPACE SCIENCES (Laidlaw Brothers, 1969).
2. Bishop, Margaret S., Phyllis G. Lewis, and Richmond L. Bronaugh. FOCUS ON EARTH SCIENCE (Merrill, 1969).
3. Earth Science Curriculum Project. INVESTIGATING THE EARTH (Houghton Mifflin, 1967).

The order is not intended to convey any preference but simply to standardize and, thus, simplify the process of finding the particular reference you are seeking. Principal supplementary references are also given for each lesson. Again, the order means little; rather, the sources cited represent the best of the sources available to the author at the time of writing. As complete a bibliography as possible is included at the end of this section. In the event that a reference is particularly valuable, it usually will be mentioned on the program preceding the one to which it applies.

The Activities Section:

The principal purpose of the activities section is to provide you with some examples of student investigations, demonstrations, or activities which lead into or serve to demonstrate a particular concept. There are literally hundreds of possible activities, and there is space in this handbook for only a few. As time permits, more will be added and distributed to you. If you know of a demonstration, investigation, or activity which is not listed, please let us know so that we may add it to our lists and inform the other teachers taking the course.

Do not feel that you must try every activity listed, but do try at least one every week. One of the best ways to keep students awake, interested, and enthusiastic is to keep them busy discovering. Most of the activities shown promote discovery and, therefore, can make learning an exciting business.

The Content Outline:

This portion of the handbook is perhaps the least valuable. First, many of the facts listed will have changed before the course is completed. More important are the major concepts embodied in the outline. We are, after all, principally interested in concepts. You should treat the outline as you would a set of course notes. Indeed, they are intended to serve as such, and we hope you will use them in place of taking notes. You should feel free to mark out, add to, make notes on, or scribble all over the entire handbook. It belongs to you. The television program will not necessarily cover all of the material in the outline or take it up in the outline order. However, the material in the lesson is vital to the concepts being considered and, hopefully, constitutes a total earth science course when taken as a complete unit of thirty-two lessons. Those activities printed in their entirety are not copyrighted and were purposely printed in a manner as to make them easily copied. Please feel free to do so.

Teacher Participation:

No course can give you any more than what you put into it. We believe that earth science can be one of the most exciting courses in the curriculum. We hope you will find the television portion interesting, stimulating, and entertaining; but what you derive from the course will depend principally on the amount of energy you expend on the follow-up activities. The success of this course depends on you. We hope you will help us make it the kind of success it can be.

TRANSMISSION SCHEDULE*
1970 - 71

Program Number	Tuesday 4:00 p.m.	Thursday 6:30 p.m.
1	September 15	September 17
2	22	24
3	29	October 1
4	October 6	8
5	13	15
6	20	22
7	27	29
8	November 3	November 5
9	10	12
10	17	19
	THANKSGIVING	THANKSGIVING
11	December 1	December 3
12	8	10
13	15	17
	CHRISTMAS	CHRISTMAS
14	January 5	January 7
15	12	14
16	19	21
17	26	28
18	February 2	February 4
19	9	11
20	16	18
21	23	25
22	March 2	March 4
23	9	11
24	16	18
25	23	25
26	30	April 1
27	April 6	EASTER
	EASTER	15
28	20	22
29	27	29
30	May 4	May 6
31	11	13
32	18	20

* The same lesson will be broadcast on Tuesday at 4:00 p.m. and Thursday at 6:30 p.m. for convenience in scheduling.

TEXT REFERENCES

1. Hibbs and Eiss. THE EARTH-SPACE SCIENCES (Laidlaw).
2. Bishop, Lewis and Bronaugh. FOCUS ON EARTH SCIENCE (Merrill).
3. ESCP. INVESTIGATING THE EARTH (Houghton Mifflin).

ADDITIONAL REFERENCES

4. Namowitz and Stone. EARTH SCIENCE, THE WORLD WE LIVE IN (Van Nostrand).
5. Navarra and Strahler. OUR PLANET IN SPACE (Harper and Row).
6. Ramsey and Burckley. MODERN EARTH SCIENCE (Holt, Rinehart and Winston).
7. Ramsey, et al. FOUNDATIONS OF PHYSICAL SCIENCE (Holt, Rinehart and Winston).
8. Thurber and Kilburn. EXPLORING EARTH SCIENCE (Allyn & Bacon).
9. Trinklein and Huffer. MODERN SPACE SCIENCE (Holt, Rinehart and Winston).
10. Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath).

COLLEGE LEVEL REFERENCES

11. Clark and Stealin. THE GEOLOGICAL EVOLUTION OF NORTH AMERICA (Ronald).
12. DICTIONARY OF GEOLOGICAL TERMS, AGI (Dolphin).
13. A DICTIONARY OF MINING AND RELATED TERMS, Department of the Interior.
14. Dunbar. HISTORICAL GEOLOGY (Wiley).
15. GEOLOGY AND EARTH SCIENCES SOURCEBOOK, AGI. (Holt, Rinehart and Winston).
16. Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman).
17. Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald).
18. Shelton. GEOLOGY ILLUSTRATED (Freeman).
19. Shepard. THE EARTH BENEATH THE SEA (Johns Hopkins).
20. Spencer. GEOLOGY: A SURVEY OF EARTH SCIENCE (Crowell).
21. Strahler. EARTH SCIENCES (Harper & Row).
22. Strahler. PHYSICAL GEOGRAPHY (Wiley).
23. Zumberge. ELEMENTS OF GEOLOGY (Wiley).

NORTH CAROLINA *

24. Broadhurst. AN INTRODUCTION TO THE TOPOGRAPHY, GEOLOGY, AND MINERAL RESOURCES OF NORTH CAROLINA (Educational Series No. 2, 1952).
25. Stuckey. NORTH CAROLINA - ITS GEOLOGY AND MINERAL RESOURCES (1965).
26. Stuckey and Steel. GEOLOGY AND MINERAL RESOURCES OF NORTH CAROLINA (Educational Series No. 3, 1953).

* Available from North Carolina Division of Mineral Resources, Department of Conservation and Development, Raleigh, North Carolina 27603.

LESSON 1, Introduction

CONSTRUCTS FOR TEACHING EARTH SCIENCE

Objectives:

1. To gain an understanding of some of the various approaches that can be used in teaching earth science and the reasoning behind their application.
2. To differentiate some of the various styles of teaching and their positive and negative points.
3. To establish a partial constructural base for the organization of the following thirty-one lessons.

References:

1. Hibbs, Albert R., and Albert F. Eiss. THE EARTH - SPACE SCIENCES (Laidlaw Brothers, 1969), Chapters 1 and 2.
2. Bishop, Margaret S., Phyllis G. Lewis, and Richmond L. Bronaugh. FOCUS ON EARTH SCIENCE (Merrill, 1969), pages iii and iv; Chapter 1, Section 1.1.
3. Earth Science Curriculum Project. INVESTIGATING THE EARTH (Houghton Mifflin, 1967), text preface and prologue, Teacher's Manual Introduction, pages 1-16.

Activities:

1. Make a list of all the various constructural schemes for teaching earth science that you can think of. Have each teacher select one and discuss its good and bad points. (Example: compare the three constructural schemes in the state adopted textbook or some of the references.)

2. Have each teacher develop a plan for their year's activity based on one or more construct, discuss and justify their plan to the rest of the group.

3. Discuss the approach you plan to use in teaching earth science this year. Will it be factual, investigative, field oriented, concept oriented, or a mixture of the different approaches? Why did you choose your particular approach?

LESSON 1

CONSTRUCTS FOR TEACHING EARTH SCIENCE

I. Major Construction Themes

A. Classical approach - proceeds systematically through the branches of the earth sciences and usually the sub-branches.

Example:
- Astronomy
- Meteorology
- Climatology
- Oceanography
- Geology --------------------
    - Mineralogy
    - Petrology
    - Geomorphology
    - Structural Geology
    - Geophysics
    - Historical

B. Historical approach - usually begins with the origin of the universe and continues to the present, inserting other concepts where they become necessary to explain events as they develop.

C. Macro to micro - proceeding from the universe to the atom.

D. Micro to macro - proceeding from the atom to the universe.

E. Through the spheres - proceeding from the exosphere to the atmosphere, hydrosphere, and lithosphere or the reverse order.

F. Concept oriented approach - involves selecting the major conceptual bases on which the science functions.

Example:
- Interface concept
- Gravity
- Energy flow
- Density
- Time
- Space
- Evolution
- Uniforitarianism
- Isostasy

II. Shotgun or topic selection?

A. Try to cover everything? This usually results in poor coverage of many things and often the end of the school year arrives with material left uncovered.

B. If you can't cover it well - don't try to cover it at all. Many teachers feel that it is better to skip a topic rather than treat it poorly. Often entire subject areas are ignored for one or more of the reasons below.

1. Lack of knowledge.

2. Lack of resources.

3. Lack of interest (either teacher or students).

4. Previous knowledge on part of students (example: space science).

5. Location (example: students in the mid-west often talk more about fossils and less about oceanography. Students in the south have little need for a comprehensive knowledge of the landforms caused by continental and valley glaciers.)

LESSON 2 , Introduction and Content

TEACHING THROUGH CONCEPTS AND INVESTIGATIONS

Objective: To develop a rationale for teaching science concepts.

References:

Mager, Robert F. PREPARING INSTRUCTIONAL OBJECTIVES (Fearon Publications, Palo Alto, California).
Sund, Robert B., and Leslie W. Trowbridge. TEACHING SCIENCE BY INQUIRY IN SECONDARY SCHOOLS (Charles E. Merrill Books, Inc. Columbus, Ohio).
Romey, William D. INQUIRY TECHNIQUES FOR TEACHING SCIENCE (Prentice Hall).

Activities:

Discussion should follow the television program. The television program will close out with a 10-minute film, "Toward Inquiry." It is hoped that the program (with film) will show the value of teaching concepts through student activity or inquiry.

Each teacher might examine and discuss the following questions:

1. Do you consider your teaching effective?

2. Is there room for improvement in your teaching?

3. Why do you teach the way you do?

4. How could you improve your teaching methods?

5. If you are aware of areas for improvements, what factors have prevented you from implementing these changes in teaching?

6. How can you and your school proceed to overcome these problems.

LESSON 3, Introduction

THE EARTH - MEMBER OF THE UNIVERSE

Objectives:

1. To locate the earth as a body in space.
2. To develop a concept of the relation between the solar system and the galaxy.
3. To develop a concept of the relationships of the members of the solar system.

References:

1. Hibbs, Albert R., and Albert F. Eiss. THE EARTH - SPACE SCIENCES (Laidlaw Brothers, 1969), Chapters 3, 4, and 5.
2. Bishop, Margaret S., Phyllis G. Lewis, and Richmond L. Bronaugh. FOCUS ON EARTH SCIENCE (Merrill, 1969), Chapter 21.
3. Earth Science Curriculum Project. INVESTIGATING THE EARTH (Houghton Mifflin, 1967), Chapters 23, 25 and 26.

Special Reference: Trinklein and Huffer. MODERN SPACE SCIENCE (Holt, Rinehart & Winston, 1961).

Activities:

1. A scale model of the solar system.

ESCP Investigation 23-4	Text 501-502 Teacher's Manual 633-635

2. Measuring the diameter of the sun.

ESCP Investigation 24-10	Text 530 Teacher's Manual 660-662

3. Investigating galaxies.

ESCP Investigation 25-7	Text 547-548 Teacher's Manual 677-679

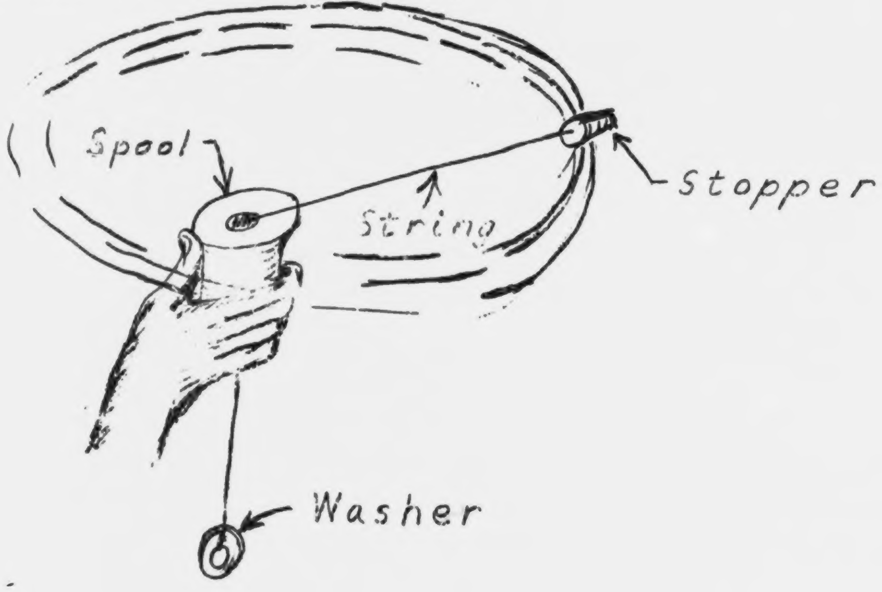
4. Gravity and inertia must be in balance in order for a planet or satellite to stay in orbit.

Materials: a piece of strong string about 5 feet long
3 or 4 heavy flat washers
a spool (or short length of glass tubing)
a rubber stopper (or some other heavy but soft object)

Pass the string through the spool, attach the washers to one end of the string and the stopper to the other (see illustration). Holding the spool above your head, twirl the stopper at proper speed so that the ball and weight balance each other. Let the string represent the force of gravity attracting the planet (stopper) to the sun (spool). Now twirl the stopper with greater force and observe that the stopper moves outward.

As the demonstration is performed, raise the following questions: (1) What happens to the period of revolution of the stopper as the radius of the string becomes greater? As the radius of the string becomes less? (2) What would happen if the string were to break while revolving about your head? Why would this occur?

Relate this demonstration to Kepler's third law, the more distant a planet is from the sun, the slower it travels in orbit about the sun. Suggest a comparison with Newton's law of gravity: as the distance increases between objects, the gravity decreases, thus the slower orbital speed. Point out one important difference between our analogy and planets in motion about the sun. There is a mechanical connection, the string, between your hand and the stopper you are twirling. There is no mechanical connection between the sun and the planets.



LESSON 3

THE EARTH - MEMBER OF THE UNIVERSE

I. Sun is just one of about 100 billion stars in a galaxy called The Milky Way. There are more than 1 billion galaxies within reach of the 200-inch Hale Telescope and many more than that in space.

  A. Galaxies are classified according to their appearance.

    1. Irregular - As name implies, they have irregular boundaries. There are great quantities of gas and dust. Some appear to be rotating and have the beginning of arms. Most stars in these galaxies are large and appear youthful.

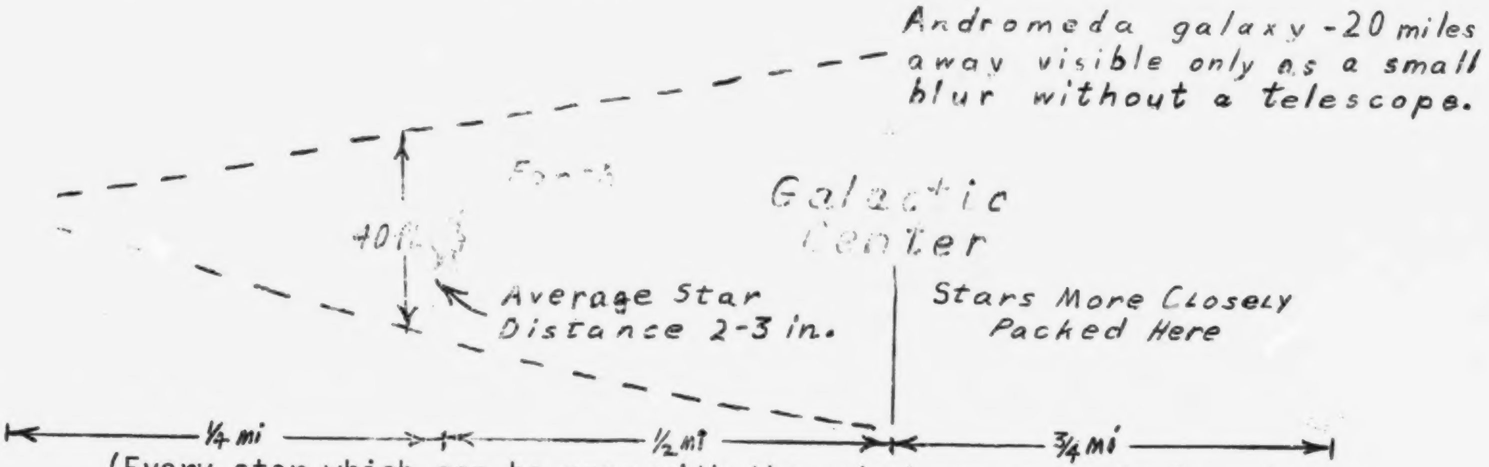
    2. Spiral galaxies - Have one or more spiral arms rotating about a relatively dense nucleus. Stars in the central hub are thought to be older than those in the spiral arms.

    3. Elliptical galaxies - Are symmetrical and range from ellipsoids or disks to spherical in shape. There is little dust or gas possibly because the material has already been formed in the stars.

II. Our own Milky Way Galaxy appears as a band of light across the sky.

  A. A spiral type galaxy (diagram). Diameter 80,000 light years

  Model: 1 inch = 1 light year


Andromeda galaxy -20 miles away visible only as a small blur without a telescope.
Earth
40 ft
Galactic Center
Average Star Distance 2-3 in.
Stars More Closely Packed Here
¼ mi
½ mi
¾ mi

  (Every star which can be seen with the naked eye as a single point of light is in our own galaxy. Only the largest telescopes can pick out single stars in other galaxies.)

  B. Closest star distance from earth in galaxy-Alpha Centuri (4.3 light years).

  C. The sun is about 2/3 of the way out from the center of the galaxy.

    1. The sun and its solar system are traveling about the galactic center at a velocity of 500,000 mi/year.

    2. One complete trip around the galaxy requires 250 million years.

III. The Solar System

A. Our solar system consists of nine planets, comets, asteroids, meteorites, dust particles, electric fields, magnetic fields, and light all moving about the sun. The Egyptian astronomer Ptolemy devised the first solar system in 130 A.D. The Ptolemic Universe was earth centered--earth was fixed, and the seven known planets were assumed to travel around the earth in circles called deferents. The planets moved in circles called epicycles which traveled along the deferents. Those were used to explain retrograde motion in the planets. As time went on, the system increased in complexity as individuals attempted to explain various motions until the system became extremely complex.

Copernicus (16th century) proposed a sun-centered universe. (This had been done much earlier but was not accepted - Greek scholar Aristarchus of Samos, 3rd century B. C.)

B. The sun is an "average" star.

1. Radius = 696,000 (6.96×10^5) Km.

2. Mass 1.99×10^{30} Kg or 332,000 times that of earth.

3. Thermonuclear fusion provides the energy which makes life possible on the earth.

C. Planets

1. Mercury -
   - a. Smallest planet
   - b. Closest to sun (36,000,000 miles)
   - c. Rotates every 58.65 earth days; revolves about sun once every 88 days. (Until 1965 Mercury was thought to rotate and revolve once every 88 days. Then Rodas' observation proved that the rotation required only 2/3 revolution.)
   - d. No atmosphere
   - e. Sun-facing surface temperature (340°C; 569°F)
   - f. So small, gravity is only 3/8 that of earth

2. Venus -
   - a. Second planet out from sun (67,200,000 miles)
   - b. Earth's closest neighbor (26,000,000 miles)
   - c. Cloudy atmosphere, no oxygen (72 - 98% CO_2; atmospheric pressure 7 - 15 times that of earth)
   - d. Temperature varies from 45°C (114°F) to 280°C (536°F)
   - e. Rotates clockwise - once every 243 earth days
   - f. Year is 224 earth days

3. Earth -
   - a. Third planet out from sun at a mean distance of 93,000,000 miles
   - b. Average temperature 56°F.

   c. Day - 24 hours
   d. Year - 365 days
   e. One natural satellite

4. Mars -
   a. 4th planet out (142,000,000 miles)
   b. Rotates every 24 hours, 37 minutes, 22.1 seconds
   c. Revolves 687 earth days
   d. Temperature range - 70°C (-100°F) - +31°C (+80°F)
   e. Atmosphere mostly CO_2; surface pressure 3/4 that of earth
   f. No magnetic field

5. Asteroids - fragments ranging from dust size to 480 miles in diameter.

NOTE: 1 - 4 Inner planets

6. Jupiter -
   a. Mean orbital distance 484,000,000 miles
   b. Volume 1,300 times that of earth
   c. Density 1/4 that of earth
   d. Atmosphere - hydrogen, methane and ammonia
   e. Gravity at surface is 2.5 times that of earth
   f. Rotates once every 9 hours, 50 minutes
   g. Revolves 11.9 earth years
   h. 12 known moons
   i. Thought to be composed largely of liquid and gas

7. Saturn -
   a. 889,000,000 miles from sun
   b. Revolves once every 29½ earth years
   c. Rotates once every 10 hours and 14 minutes
   d. 95 times larger than the earth
   e. Rings (171,000 miles in diameter and 10-20 miles thick
   f. Has 10 moons
   g. Atmosphere - surface cloud covered
   h. Composition probably mostly gas

8. Uranus -
   a. Composed primarily of gas
   b. Diameter 4 times that of earth
   c. 1,784,000,000 miles from sun
   d. Revolves once every 84 earth years
   e. Rotates once every 10 hours and 49 minutes
   f. Axis of rotation lies in orbital plane

9. Neptune -
   a. 2,800,000,000 miles from sun
   b. Orbits once every 165 years
   c. Diameter 28,000 miles, density 0.4 x earth
   d. Composition gaseous
   e. 2 moons

10. Pluto -
   a. Discovered 1930
   b. Diameter estimated 36,000 miles
   c. Orbit varies from 2,700,000,000 miles perihelion to 4,600,000,000 miles aphelion
   d. Orbit requires 248 years

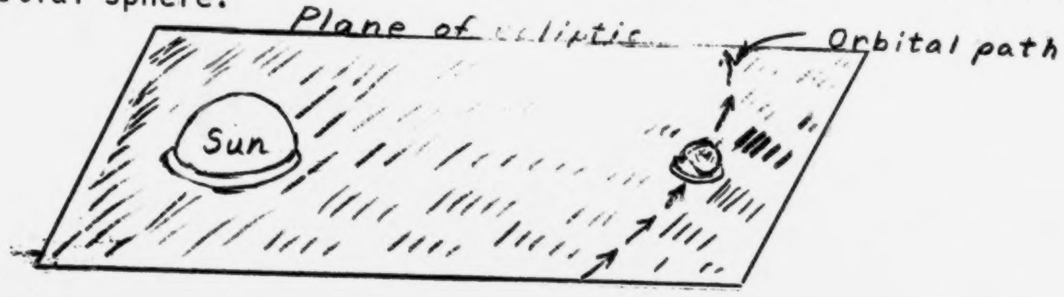
D. Plane of Rotation

The planets of the solar system all revolve in a band which varies from a perfect plane by a maximum of 7^{0} with the exception of Pluto. Thus, they move in a band of sky known as the Zodiac.

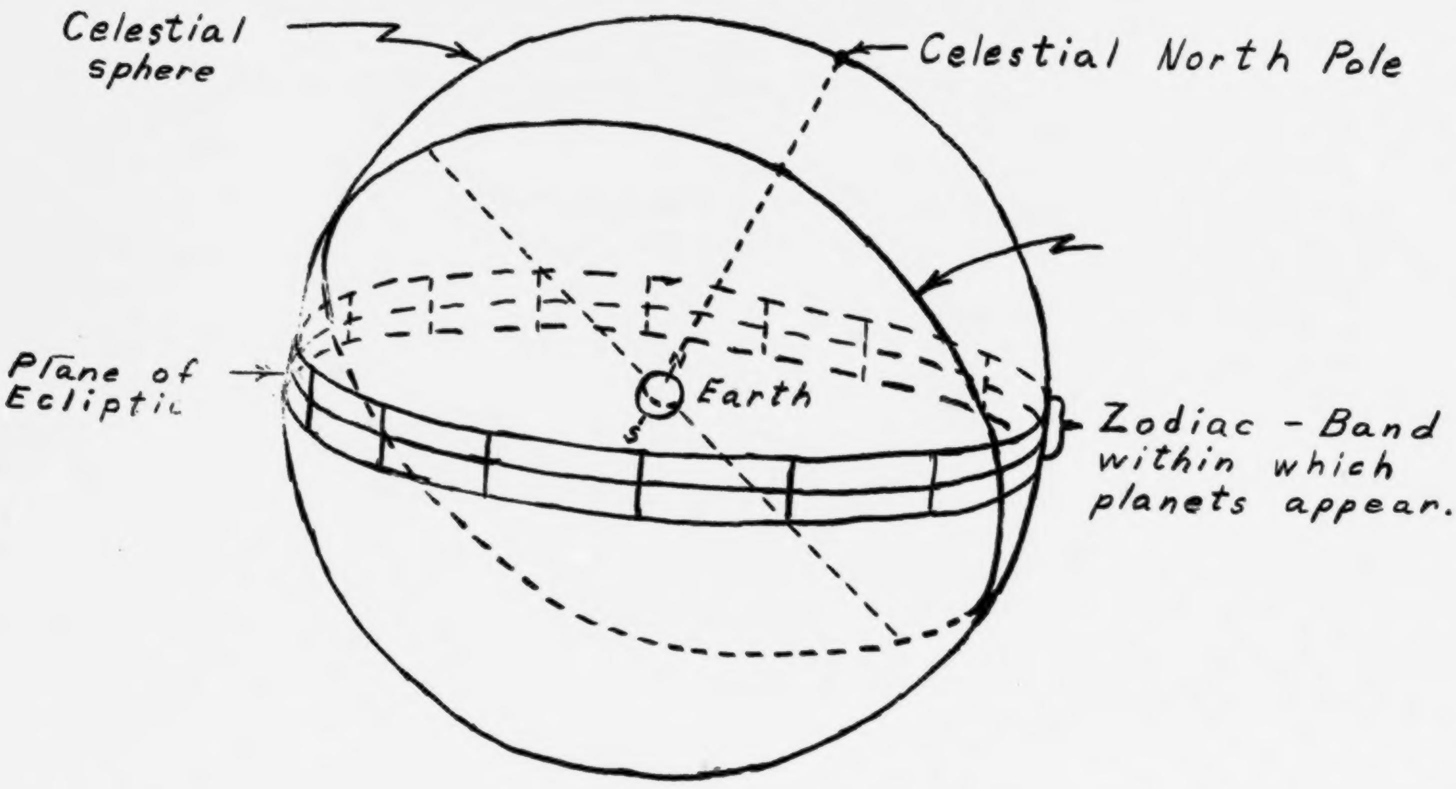
1. Constellations found along band known as Zodiac:

   a. Aquarius
   b. Pisces
   c. Aries
   d. Taurus
   e. Gemini
   f. Cancer
   g. Leo
   h. Virgo
   i. Libra
   j. Scorpius
   k. Sagittarius
   l. Capricornus

E. Ecliptic is the path along which the planets appear to travel on the celestial sphere.


Plane of ecliptic
Orbital path
Sun

Celestial sphere - A sphere of infinite radius with all the stars except the sun located on its surface.
Celestial equator- A projection of the earth's equator on the celestial sphere.
Celestial poles - The projection of the N and S poles on the celestial spheres.


Celestial sphere
Celestial North Pole
Plane of Ecliptic
Earth
S
Zodiac - Band within which planets appear.

LESSON 4, Introduction

THE EARTH - PLANET IN SPACE

Objectives:

1. To understand the motions of the earth.
2. To develop a concept of seasons on the earth as they are related to motions in the solar system.
3. To develop a concept of time as a function of rotation.
4. To comprehend the dimensions of the planet.

References:

1. THE EARTH - SPACE SCIENCES, Chapter 12, pages 220-226
2. FOCUS ON EARTH SCIENCE, Chapter 1, pages 4-12; Chapter 2, pages 24-35
3. INVESTIGATING THE EARTH, Chapter 3, pages 58-80 (Teacher's Manual 92-119); Chapter 4, pages 82-102 (Teacher's Manual 120-145)

Special References:

Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, Inc., 1961), Chapters 1, 4, 5, 6

Trinklein and Huffer. MODERN SPACE SCIENCE (Holt, Rinehart & Winston, 1961), Chapter 4

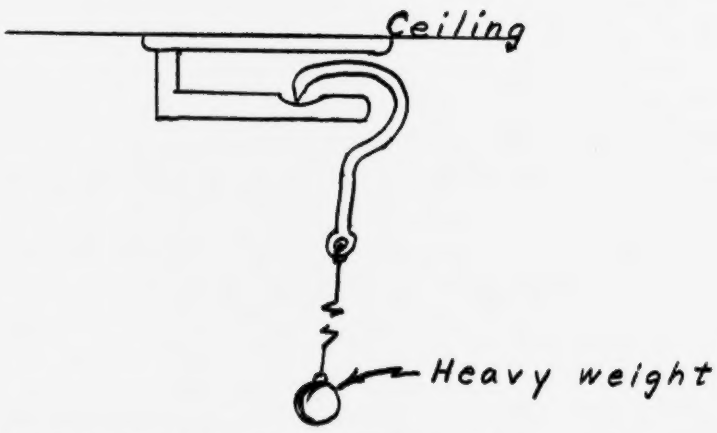
Activities (involving equipment):

1. Show the earth's rotation by means of the Foucault pendulum.

Materials: heavy metal ball (such as a 16 lb shot)
long wire (15 or 20 feet)
steel hook
suspension bracket
room with high ceiling (gymnasium or auditorium)
Hook mounted on the wall

The heavy ball is to be hung at the end of the long wire, from a suspension bracket in ceiling. The steel hook must be sharpened and rest in a depression ground in the bracket as sketched below. Pull the pendulum aside and tie it by a fine thread to a hook in the wall. When it has become perfectly still, burn the thread. This releases the pendulum without any disturbance. The pendulum will continue to swing while the room turns because of the earth's rotation. Since the support is practically frictionless, the rotation of the room is not communicated to the pendulum. In the northern hemisphere the south end of the swing will gradually shift westward, and the change can be noted in half an hour or more. Care should be taken that no air currents disturb the motion.

The significance of this experiment can be explained by mounting a simple pendulum on a rotating stool. Any small heavy object can be suspended from a clamp mounted on a stand which is set on the stool. Start the pendulum swinging, and then turn the stool under it. The pendulum keeps swinging in same plane, which does not change when stool and pendulum support rotate.



This investigation can be simulated by demonstration. The materials required include a rotating platform (piano stool, etc.), wastebasket, stick, string, and a small heavy weight. Place the empty wastebasket on the seat of the rotating piano stool. Tie a string to the weight and fasten the other end to the stick. Place the stick across the top of the wastebasket and start the pendulum swinging. Then rotate the stool seat along with the basket. Notice that the path of the pendulum does not change as the basket turns.

2. Investigating motions in the sky ESCP Investigation 4-1	Text 84 Teacher's Manual 123-126
3. Investigating positions on a sphere ESCP Investigation 3-2	Text 63 Teacher's Manual 96-99
4. You can measure the earth ESCP Investigation 3-5	Text 68-69 Teacher's Manual 102-106

Activities (involving little or no equipment):

1. Determine the apparent rotation of the sky due to the earth's rotation.

Materials: star chart
plumb line (string and weight). Instead of the plumb line, the vertical edge or corner of a building will serve very well, if such is available. Do not use posts or telephone poles; they may not be exactly vertical.
pencil and paper
watch or clock

a. Choose a location from which the whole northern sky is visible, including parts close to the horizon. Identify the North Star (Polaris), Big Dipper, and Cassiopeia. Holding the plumb line steady at arm's length so that it seems to pass right through Polaris, observe carefully where its lower end appears against the stars of the Big Dipper or Cassiopeia (or between them). Draw a line on the star chart to represent this position of the plumb line, and note the time to nearest minute. Make the same type of observation two or three hours later, mark lines on chart, and note the time. Also record the calendar date. In which direction does the sky appear to turn? (Clockwise or counterclockwise?) Relate this to the earth's rotation: if you looked down on the north pole of the earth, how would the earth seem to turn? (Clockwise or counterclockwise?)

Measure the angle between the two lines with a protractor. How many degrees is it? Calculate the change in degrees per hour. From this, calculate the time required for one complete rotation (360°). What conclusion can be drawn from this result? How accurate do you think your result is? This observation may be supplemented by photographic star trails.

b. Stand in a particular spot that can be exactly identified later. Identify one of the prominent constellations in the southern sky (e.g., Orion) and sketch its position relative to prominent landmarks (buildings, trees, etc.). Note the time. Two or three hours later, standing at exactly the same spot, again observe the same constellation, sketch its position, and note the time. How does the change of position of this constellation fit in with the change you observed in the north? Would its period for one complete rotation differ from that of the northern sky?

c. Observe a constellation that appears low in the eastern sky, and observe it two hours later. Explain the changes.

d. Observe a constellation that is about midway up in the western sky, and observe again two hours later. Explain the changes.

2. Drawing the earth to scale ESCP Text 73
   Teacher's Manual 107

3. Spinning bodies precess on their axes. Obtain a small toy gyroscope or wooden top. Start the top or gyroscope spinning and place on any flat surface. Notice as the spinning slows that the axis will begin to wobble or precess.

4. Using your school flagpole or any other tall slender object, record the shadow made on the ground at noon several times a month during the school year. (See Strahler, PHYSICAL GEOGRAPHY, pages 87-88.)

LESSON 4

I. Motions of the Earth

A. The earth's motions can be summarized as follows:

1. The sun and its solar system move with the galaxy and rotate about the galactic center.

2. The earth revolves about the sun.

3. The earth rotates and precesses on its axis.

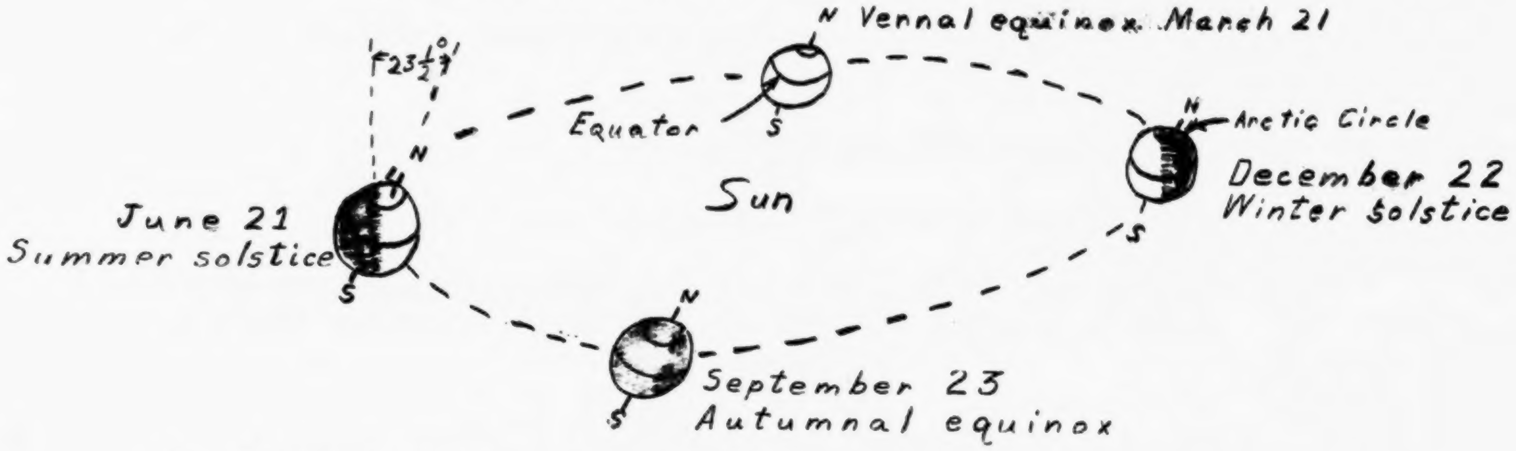
B. We have discussed the path of the sun in the galaxy and it can be summed up as being located about 2/3 (27,000 light years) of the way out from the center of the galaxy and traveling about that center at a speed of 220 Km/sec (136 mi/sec). Therefore, it takes about 220,000,000 years to complete one revolution about the galactic center.

C. The revolution of the earth about the sun enables us to determine a year.

1. Because of the tilt of the earth's axis the seasons occur.

a. The tilt of the earth's axis is 23½° to the orbital plane.

b. The tilt is always the same--the North Pole is always oriented toward the pole star, Polaris.


N
Vernal equinox March 21
23½°
Equator
S
N
Arctic Circle
December 22
Winter Solstice
S
Sun
N
June 21
Summer solstice
S
N
September 23
Autumnal equinox
S

2. On March 21 (vernal equinox) the sun first shines on the North Pole.

a. The sun is directly overhead at the equator.

b. Until September 23 the sun will be seen directly overhead north of the equator.

3. On June 21 (summer solstice) the sun reaches the most northward position where it is directly overhead.

a. This position is located at 23½° north latitude and is called the Tropic of Cancer.

b. At any point north of the Tropic of Cancer, the sun will always be seen in the southern part of the sky.

c. The sun does not appear above the horizon within the Anarctic Circle on this day ($66\frac{1}{2}^{\circ}$ south latitude).

4. On September 23 (autumnal equinox) the sun has returned to a position directly overhead at the equator.

a. The sun will now be seen for the first time at the South Pole.

b. The sun is not now visible from the North Pole.

5. On December 21 (winter solstice) the sun is directly overhead at the Tropic of Capricorn ($23\frac{1}{2}^{\circ}$ south latitude). This is the farthest point south of the equator at which the sun will be seen directly overhead.

a. At the time of winter solstice, the northern hemisphere receives the least heat from the sun.

b. The lowest winter temperatures occur after this date because of the "lag" in heating and cooling of the earth.

c. Sun does not rise on this day within the Arctic Circle ($66\frac{1}{2}^{\circ}$ north latitude).

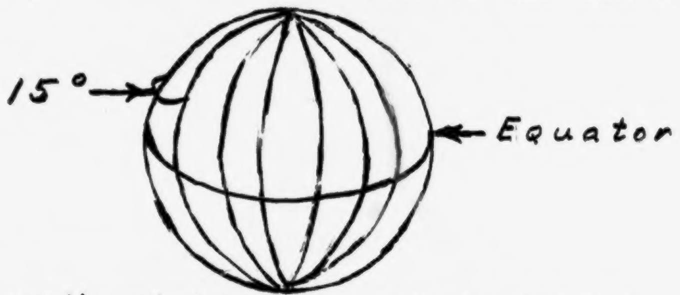
6. The length of time from one vernal equinox to another is known as a Tropical Year (365 days, 5 hours, 48 minutes, and 46 seconds).

D. The rotation of the earth on its axis establishes a measure of time called a day.

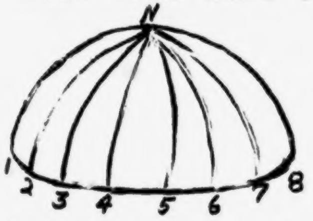
1. The earth rotates 360° in 24 hours.

a. 360° divided by 24 hours equals 15° per hour.

b. Thus an hour is equal to rotating 15° or traveling around the earth to a point 15° east or west of the starting location.



c. Since the earth rotates from west to east time progresses from east to west.



d. The contiguous United States has four time zones.

(1) Eastern Standard Time
(2) Central Standard Time

(3) Mountain Standard Time
(4) Pacific Standard Time

2. The rotation of the earth may be demonstrated by:

   a. The apparent motion of the sun from east to west.

   b. The apparent rotation of stars about the pole star, Polaris.

   c. The Foucault pendulum.

   d. More recent methods involve the use of satellites.

      (1) Satellites travel about the earth in a single orbital plane.
      (2) As the earth rotates, the satellite's orbit appears to be slipping westward.

E. The earth wobbles on its axis. This motion is called Precession and is like the spinning of a top as it (top) slows down.

1. The earth's axis slowly makes a circle, taking 26,000 years to complete one circle.

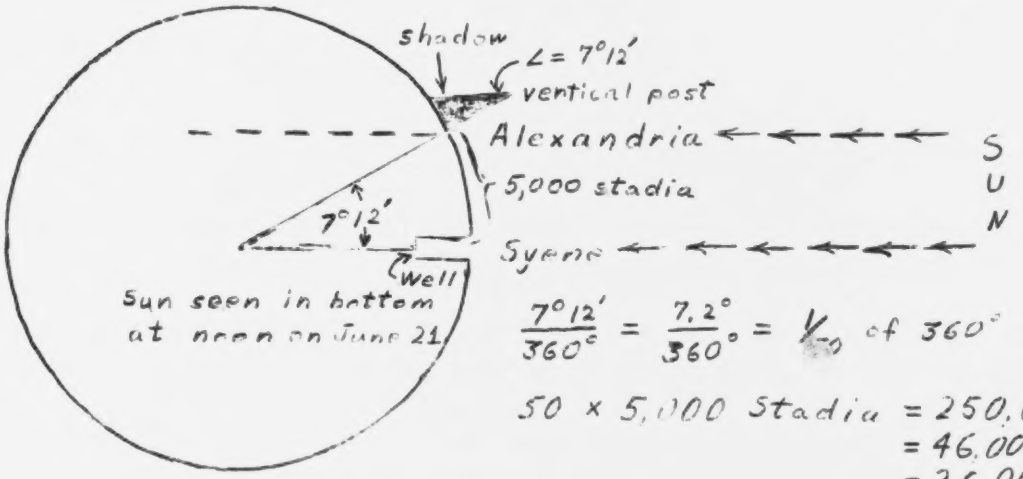
2. This circle also varies slightly due to the uneven pull of the moon and the sun.

II. Size and Shape of the Earth

A. First determined by Eratosthenes (Greek mathematician and astronomer, about 200 B.C.)

Stadium - (Staed' ee um) - ancient unit of distance equal to about 185 meters.

Variables - 1. Well walls not perpendicular
2. Distance to syene not accurately measured



$$\frac{7^\circ 12'}{360^\circ} = \frac{7.2^\circ}{360^\circ} = \frac{1}{50} \text{ of } 360^\circ$$

$50 \times 5{,}000$ Stadia = 250,000 Stadia
= 46,000 Km.
= 26,000 mi.

Measurement amazingly accurate

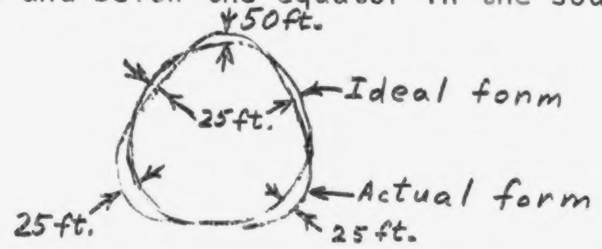
Eratosthenes' measurement = 26,660 miles

Present day value at equator = 24,902 miles

At the time he accomplished this, he was the head of the library at Alexandria which was the greatest institution of learning in the ancient world.

B. The earth was considered round until Sir Isaac Newton reasoned that the force of rotation was powerful enough to cause a slight flattening at the poles. This was proven in 1743 when the earth's circumference at the equator was found to be slightly greater than the circumference around the poles.

C. The earth today is treated as a slightly pear-shaped body with bulges at the north pole and below the equator in the southern hemisphere.



Spheroid - a figure slightly different from a sphere.
Oblate - flattened or depressed at the poles.

D. Earth statistics

Axes Length	N/S Axis	Equatorial Axis
(1960) US Army Map Service	6,378,160 mi	6,356,778 mi
(1909) International Standard	6,378,388 mi	6,356,912 mi

Values for earth radii are adopted by the International Union of Geodesy and Geophysics.

Polar radius	3,951 miles	6,357 Km
Equatorial radius	3,964 miles	6,378 Km
Mean radius	3,960 miles	6,367 Km

III. The Mass and Density of the Earth

A. Newton's Law of Gravitation says that the force of attraction between two objects depends upon the mass of each.

B. Scientists have developed a delicate pendulum with which they can measure the force of gravity between two standard weights. This value is called the gravitational constant.

C. Once the gravitational constant was known, the mass of the earth could be determined. The mass is 5.98×10^{27} grams (6.6×10^{21} tons).

D. Knowing the size and shape of the earth, we can calculate its volume.

$$\frac{4\pi r^3}{3} \cong \frac{4 \times 3.14 \times (3{,}690)^3}{3} \cong 260 \text{ billion mi}^3$$

E. Density is the relation of mass to volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

F. Therefore, knowing the mass and volume of the earth, we can determine its density. (5.522 gm/cm^3)

LESSON 5, Introduction

LOCATION AND MAPPING

Objectives:

1. To insure an understanding of locating a given point on the earth's surface.
2. To develop a concept of the problems involved in portraying a sphere on a flat surface.
3. To introduce mapping illustrating a map's uses, function, and organization.

References:

INVESTIGATING THE EARTH, Chapter 3, Index

Special References:

Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 1 and 2
Namowitz and Stone. EARTH SCIENCE: THE WORLD WE LIVE IN (Van Nostrand, New York), Chapters 5 and 29
MAP READING FM 21-26. Army Field Manual. Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.
Teacher's Packet of Geologic Materials: 1. Topographic Maps Pamphlet
2. Geologic Maps Pamphlet
MAP PROJECTIONS FOR MODERN CHARTING, U. S. Coast and Geodetic Survey

Activities:

1. Investigating positions on a sphere.
   ESCP Investigation 3-2 — Text 63
   Teacher's Manual 96-99
2. Map Projections P 6-7, Project Ideas in the Earth Sciences, teacher's packet of geologic materials.
3. Projection problems. Place a light source inside a boiling flask on which you have previously laid out a geographic grid. Try setting up various types of projections and see what types of distortion occur.

LABORATORY ACTIVITY: TOPOGRAPHIC MAPPING

In this activity you will review the fundamental features of Topographic Maps and the methods involved in their reading. Feel free to refer to the accompanying map.

1. Name the type of feature indicated in a topographic map by each of the following colors:

   a. Blue________________ d. Brown________________________

   b. Black________________ e. Red (overprint) ______________

   c. Green________________

2. Show three ways of indicating scale on a map.

   a.

   b.

   c.

3. What is a contour line? ____

   ____

4. What does contour interval mean? ______________________________

   ____

5. In what type of terrain is it best to use:

   a. A small contour interval ____________________________

   b. A large contour interval ____________________________

6. In the spaces below show each of the following features using contour lines:

   a. A V-shaped valley in which a stream is flowing (use 4 contour lines):

b. A hill 4 contours high:

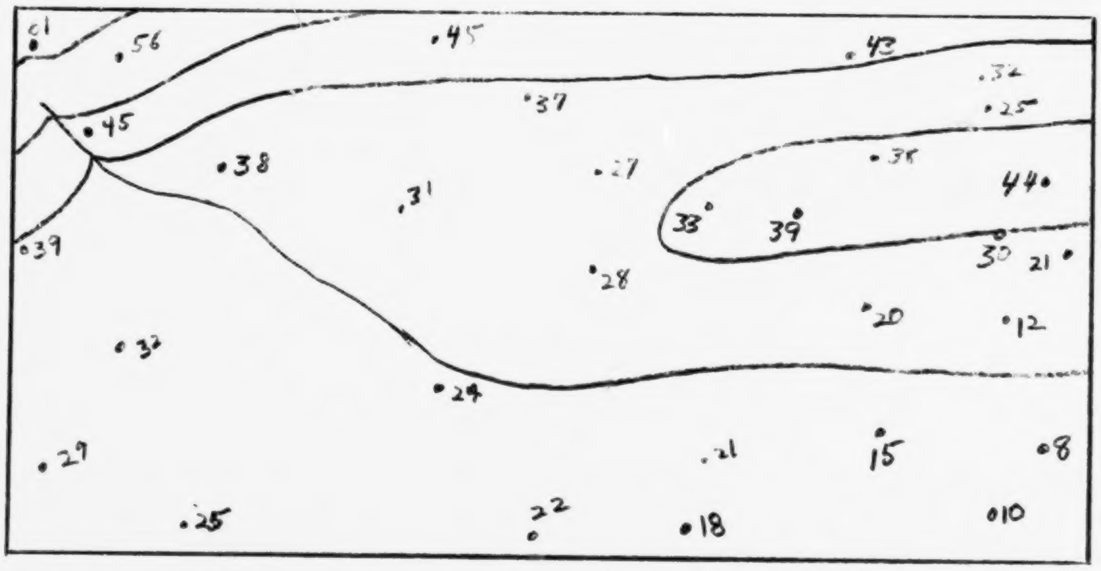
c. A depression 3 contours deep:

d. A ridge with two peaks:

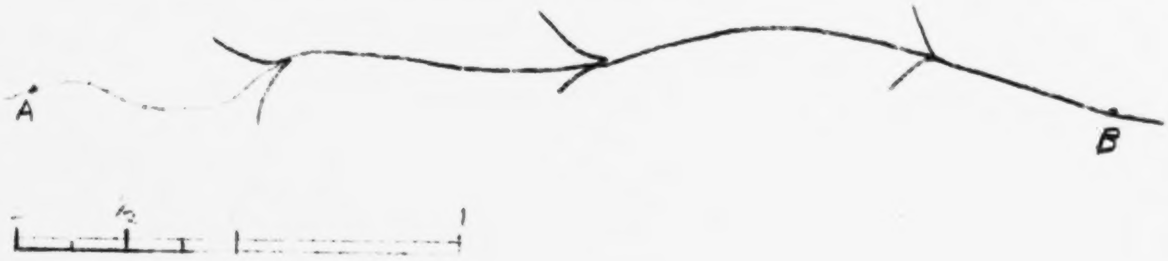
7. Using a scale of 1" = 1 mile and a ten foot contour interval draw an island with the following characteristics. The island is three miles wide North-South and five miles long East-West. The island reaches a height of 90 feet and slopes gently Westward from a peak on the eastern end of the island. A stream flows down the Eastern slope and a cliff-like slope marks the Western end of the island.

8. The map below represents an area which has been surveyed but in which the contour lines have not been drawn. Two contour lines have been drawn to help you get started. Now it's up to you to complete the map. Before you start, explain why a contour interval of 20 feet was chosen. ____

____

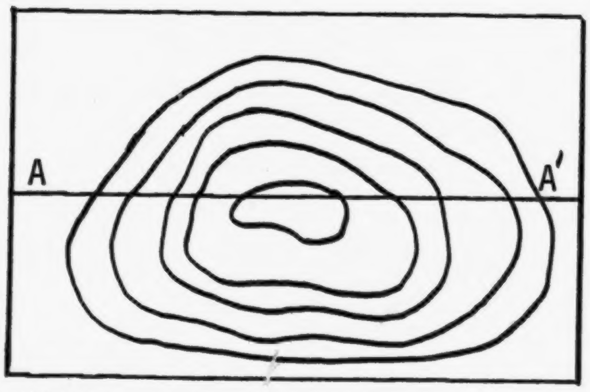


9. Measure the distance along the creek shown from point A to point B. Use the straight edge of a piece of paper to mark off the distance and compare it with the graphic scale.

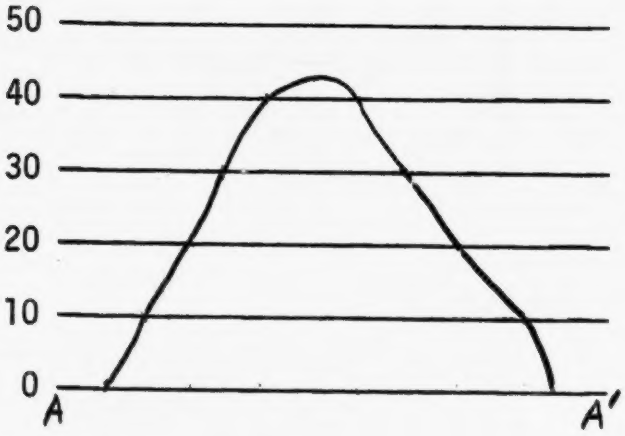


10. One of the most valuable techniques that can be used with topographic maps is a profile or section. A profile or section is a silhouette of the elevations along a given line. It shows what the land would look like if cut vertically along that base line. To construct a section, place a strip of paper along the base line and mark the points where the contour lines and the base line intersect. Write the elevations next to each point on the strip. Construct a series of lines at each elevation. (This has been done for you in the first three examples.) Transfer the elevations from the strip to the line and connect the points with a smooth line. This line is a profile or section of the terrain along the base line.

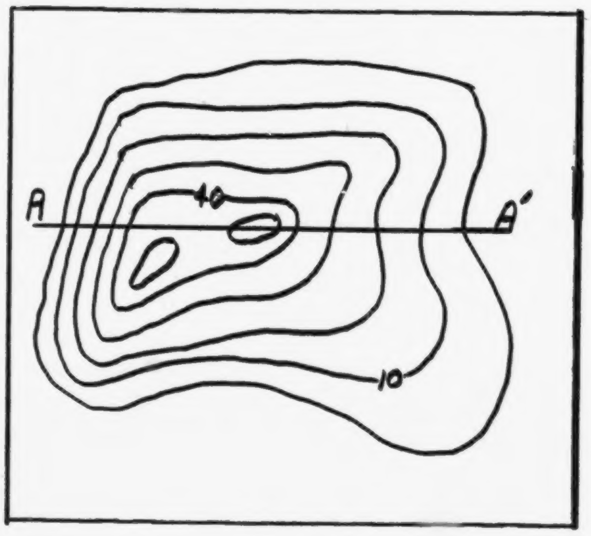
Example:



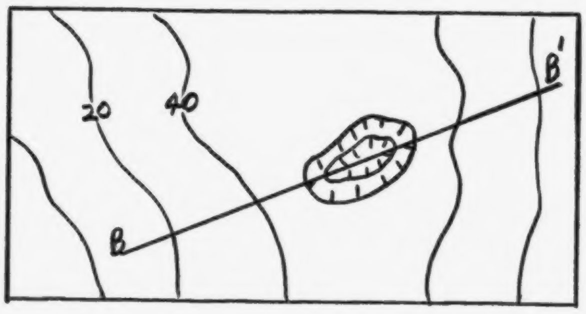
10 ft. interval



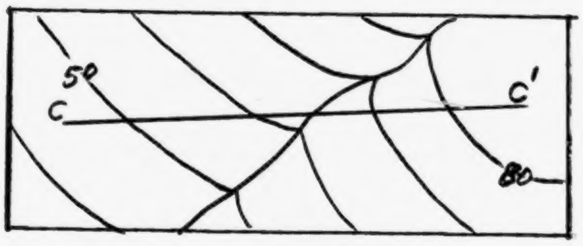
Section a.



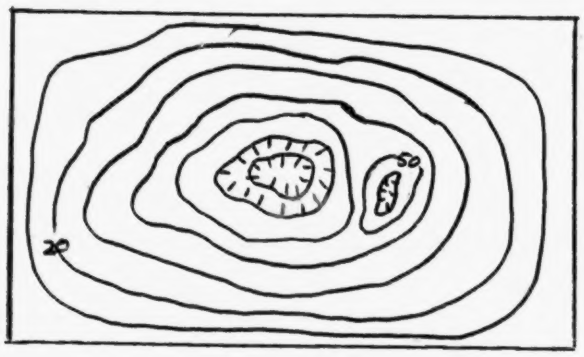
Section b.



Section c.



Section d.



LESSON 5

LOCATION AND MAPS

I. Location

A. Direction on the earth

1. If the earth did not rotate, locating a position on its surface would be very difficult.

a. Spheres have no top, bottom, or sides.

b. Directions can only be defined if some reference point is given.

2. Since the earth rotates, the ends of its axis (north and south poles) provide the reference points needed to determine direction.

a. The north-south direction extends along a line connecting the two poles.

b. The east-west direction extends along a line at right angles to the north-south line.

3. The basis of today's system was invented by the ancient Greeks.

a. They devised the imaginary line system of north-south and east-west directions.

b. Ancient Greeks believed the world was round.

c. These lines crossed Greece since it was considered to be the center of the world.

(1) Places were located by their distances from these lines.
(2) The system later expanded to include seven lines, each passing through an important city.

B. Location on the earth can be established by sighting heavenly bodies.

1. Polaris, the star located nearly over the North Pole can be used to determine position. (Other stars and constellations can be used in a similar manner, but this method involves more calculations.)

2. The sun, since it appears to rise in the east and set in the west, can be used to determine east and west.

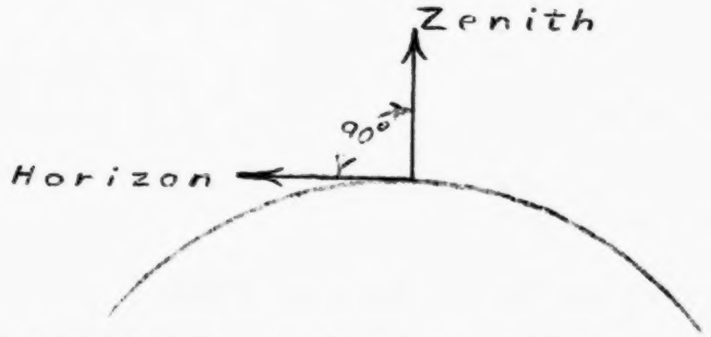
3. Locating direction and position by observation of heavenly bodies is called celestial navigation.

a. Celestial navigation is one of the oldest and most widely used methods of navigation.

b. Latitude (in the northern hemisphere) is established by sighting the angle of Polaris.

c. The Zenith is the point directly overhead in the sky (90^{o}).

d. The angle of the horizon is 0°.



C. Latitude--In describing position on the earth's surface, changes in a north-south direction are indicated by use of a system of lines parallel to the equator.

1. This system of lines on the earth's surface is determined by celestial sighting.

2. The distance from the equator to either of the poles is 1/4 of a full circle or 90°.

3. The equator is labeled 0° latitude. Polaris is visible on the horizon (0° angle).

4. Positions north or south of the equator are given in degrees (°), minutes ('), and seconds ("), plus a symbol to indicate north or south latitude.

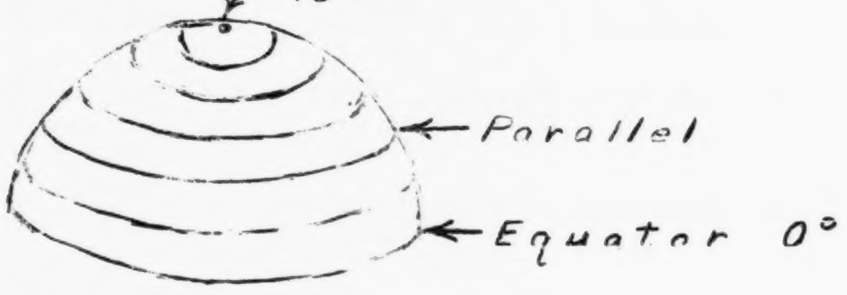
   a. North latitude includes all parallels between the equator and the North Pole.

   b. South latitude includes those between the equator and the South Pole.

5. A degree of latitude is equal to approximately 70 miles.

   a. 1/60 of a degree is one minute or about one nautical mile.

   b. 1/60 of a minute is one second or about 100 feet.



D. Longitude--the east-west position of a place.

1. A meridian of longitude is an imaginary line drawn from the North Pole to the South Pole.

   a. Meridians are divided in the same manner as parallels into degrees, minutes, and seconds.

   b. Since there is no natural starting place, an initial or prime meridian was established by international agreement.

   c. The prime meridian (0^{o}) passes through Greenwich, England, and locations are given in east or west longitude from that point.

      (1) East and west longitudes each extend only halfway around the earth.
      (2) The 180^{o} meridian (directly opposite the 0^{o} meridian) separates east and west longitude.

2. Longitude is more difficult to determine than latitude because it involves the measuring of local time at a place and comparing it to the time at Greenwich at the same instant.

   a. The earth rotates 360^{o} in 24 hours (15^{o} per hour).

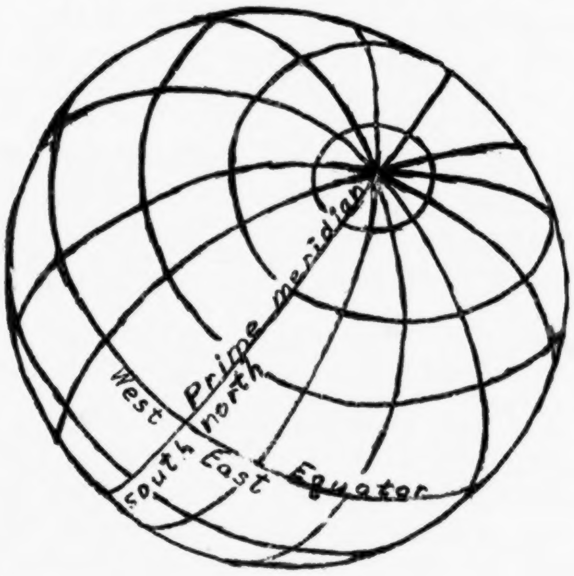
   b. Each 15^{o} of longitude equals one hour of time difference.

   c. This time is local sun time, not necessarily the "standard time-zone time."

   d. Because time sequences run for only 12 hours, longitude must be given both "East of Greenwich" and "West of Greenwich."

E. Location--To fix the position of any location on earth, latitude and longitude coordinates must both be given. (Exceptions: North and South Poles)

   1. Example: Washington, D. C. 38^{o} 53' N; 77^{o} 1' W.

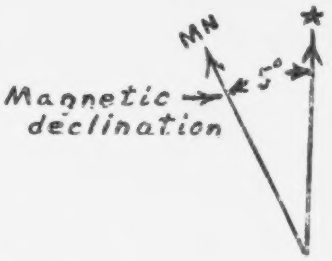


   2. Magnetic Poles

      a. In navigation, the most important factor is the direction of travel. One way of determining this is the compass.

         (1) The magnetic compass is basically a magnetized needle.
            (a) The earth is a giant magnet whose lines of force run in a north-south direction.
            (b) The needle of any magnetic compass tends to line up with the earth's magnetic field.
            (c) The magnetic compass does NOT point to TRUE north (The

        (d) The locations of the magnetic poles vary from place to place and from time to time.
        (e) The difference between magnetic north and true north is called magnetic declination.
        (f) Magnetic declination is measured in degrees east or west of north and is shown on special "isogonic" maps.
        (g) Magnetic declination is shown on other maps by means of a declination diagram.



    (2) There are several other types of compasses.
        (a) Gyro compass
        (b) Radio compass

b. Celestial sighting is also used to determine true direction.

3. Mapping

a. Functions and kinds

    (1) Maps are necessary and important to man.
        (a) There are many types of maps--road maps, political maps, geographical maps, weather maps, climatological maps, topographic maps, geologic maps, hydrologic maps, and navigational charts--to name but a few.
        (b) Each kind of map is adapted to serve a particular purpose.

    (2) Maps serve to guide men from place to place, aid in studying a particular area, bring the earth's surface into the laboratory, cut costs and speed up engineering work or planning, and assist with many other functions.

b. Map Projections

    (1) Since the earth is spherical, it can be shown without distortion only on another sphere (globe).
    (2) Any attempt to transfer the curved surface of the earth to the flat plane of a map introduces distortion.
        (a) Maps of small areas of the earth's surface have only slight distortion.
        (b) Maps of large areas tend to have great distortion.
    (3) Projections are methods of transferring the curved surface of the earth onto the flat (plane) surface of a map.
        (a) NO projection can be made that avoids all distortion.
        (b) Some projections show shape correctly while others show directions correctly.
        (c) For any given map, the projection must be chosen according to the needs of the user.

(4) Types of projections
  (a) Projections based on a cylinder
    - Cylindrical projections represent equatorial areas accurately but have great distortion in the polar areas.
    - Mercator (a type of cylindrical projection) spaces the parallels farther apart in the higher latitudes, gives the land proper shape but exaggerates size, and is useful in navigation because all compass courses are straight lines.
  (b) Projections based on a plane
    - Geomonic (all but very small areas badly distorted). Great circle routes are shown as straight lines.
    - Polar projections are geomonic projections of the polar areas. They are normally used because they are the best of the possible projections for polar areas.
  (c) Projections based on a cone
    - Conic (shows a relatively small area distortion "free").
    - Polyconic (uses a series of cones fitted together to form a larger distortion "free" map). Most maps used for field work or to portray land surface in the U. S. utilize polyconic projection.

LESSON 6, Introduction

MAPPING

Objectives:

1. To develop an understanding of how maps are constructed.
2. To develop a concept of the function of contour lines.
3. To develop a facility in reading and interpreting topographic maps.

References:

INVESTIGATING THE EARTH, Chapter 3

Special References:

Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, Inc., New York), Chapters 1, 2 and 3
Namowitz and Stone. EARTH SCIENCE: THE WORLD WE LIVE IN (Van Nostrand, New York), Chapters 5 and 29
MAP READING FM 21-26. Army Field Manual, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.
INTRODUCING MARVIN MARKER. U. S. Coast and Geodetic Survey, Washington, D. C.
Teacher's Packet of Geologic Materials:
1. Topographic Maps Pamphlet
2. Geologic Maps Pamphlet
3. Index to Topographic Mapping For North Carolina

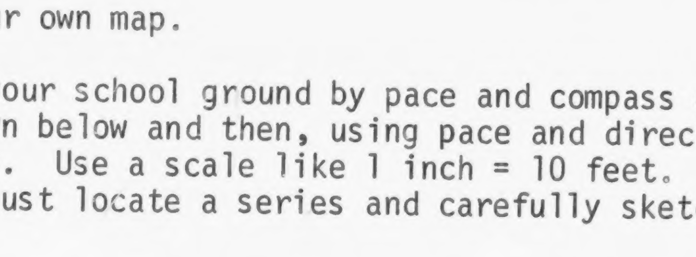
Activities:

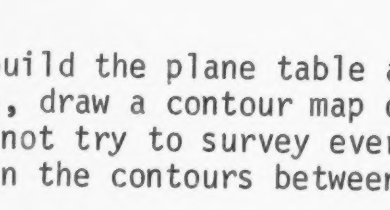
1. Investigating maps as models
   ESCP Investigation 3-9 — Text 76-79; Teacher's Manual 109-113

2. Make your own map.

   Survey your school ground by pace and compass or build the plane table and rod shown below and then, using pace and direction, draw a contour map of the area. Use a scale like 1 inch = 10 feet. Do not try to survey every point--just locate a series and carefully sketch in the contours between points.

   Make your own plane table from 3/4 inch plywood and cut it 18 inches wide by 24 inches long. Make the tripod by cutting a 6 inch circle and fastening three 1" x 3" pieces of wood to it as shown. Cut 6 pieces for legs, 3/8" wide and 3 3/4' long.

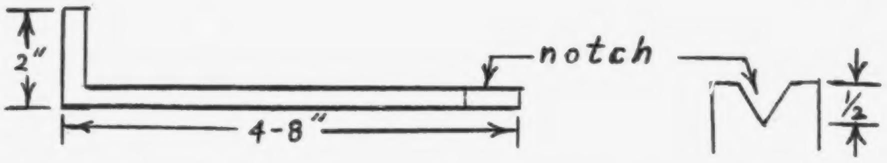




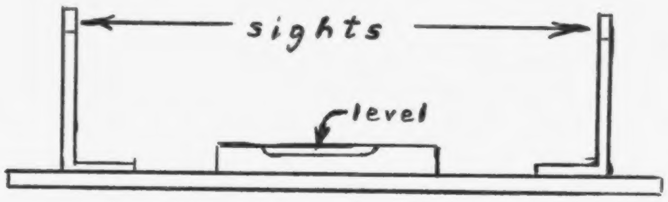
Attach them to the tripod base with screws and fasten them together at the bottom with screws. Drill and countersink a hole through the table and tripod base. Mount the plane table to the base with a bolt and wing nut.

Construct your stadia rod from a piece of 1" x 2" wood at least 6 feet long. Mark the rod off in feet and inches and paint it in contrasting colors (for example, black or red on a white background).

Your alidade can be made from a ruler. Bend two strips of metal and notch each as shown below.



Glue the strips to the ends of ruler and, if possible, also glue a small bubble level to the ruler center.



3. Map Revision, Page 7, PROJECT IDEAS IN THE EARTH SCIENCES, Packet of Geologic Materials.

LESSON 6

MAPPING

I. Basic Map Design (all maps contain the following information.)

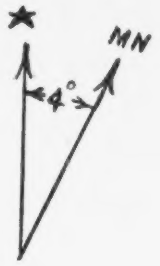
A. Compass direction

1. The standard method of showing direction on a map is to make the top of the map north.

2. As you look at a map, the top is north; the bottom is south; the right is east; and the left is west.

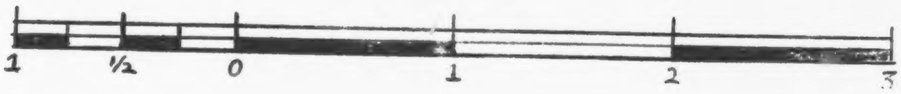
B. Latitude and longitude. Because of the standard map orientation, the meridians run from top to bottom and parallels run from left to right.

C. Declination diagram. Since magnetic north and true north are usually not the same, a diagram is used to indicate the difference.



D. Scale - the relationship between distance on the map and distance on the ground. Scale may be shown in three ways.

1. Graphic Scale:



2. The representative fraction (RF) is expressed as a fraction. For example, 1/10,000 means that one unit of any kind on the map equals ten thousand of the same units on the ground.

3. Verbal Scale - a worded statement of scale (example, "One inch equals a mile."

4. The other symbols and information shown on a map will vary according to the purpose of the map.

II. Topographic Maps:

Although the earth sciences employ nearly every imaginable type of map, we shall discuss topographic maps as a beginning point because they are the most commonly used type of map.

A. A topographic map is a graphic representation of selected man-made and natural features of a portion of the earth's surface plotted to a given scale.

1. The distinguishing characteristic of a topographic map is the portrayal of the shape and elevation of the terrain.

2. They also show the location and shape of mountains, valleys, and plains; the network of streams and rivers; and the principal works of man.

B. Map Making Agencies

1. The governments of most countries make topographic maps of their territory for military, scientific, and commercial use.

2. The United States Geological Survey is responsible for topographic mapping in the United States and its territories.

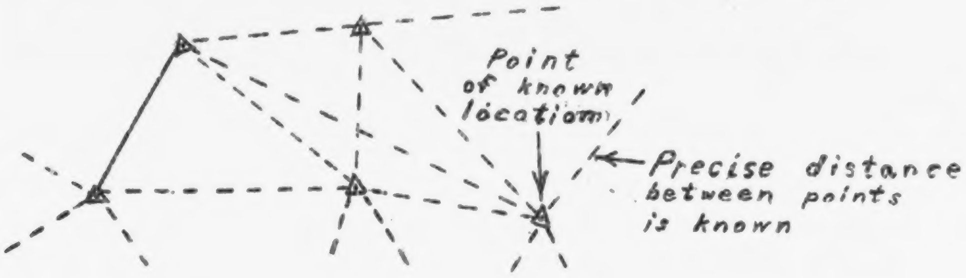
C. Making a Topographic Map

1. Survey crews establish a triangulation network of known distances between prominent points on the ground.

a. A base line is established.

(1) Very accurate measurement is required when establishing a base line. A special tape is used, 160 feet long, and laid down 33 times per mile.
(2) The base line is five miles long and is measured and remeasured until the measurements average five miles and one inch.

b. Using a transit, angles are measured to a third point from the ends of the base line completing a triangle.



These triangles can then be extended to establish a series of points whose positions are known precisely.

c. A second survey establishes points whose elevation is precisely known as leveling.

d. The points of known location and elevation are marked with brass markers known as "bench markers."

2. High altitude aerial photographs are made of the area to be mapped.

3. The photographs are precisely located by pinpointing the bench marks on the photographs.

4. The photographs are correlated in the stereo pairs and projected using a stereo plotting instrument.

picture of the earth's surface, the compiler completes a rough map.

5. The completed rough map is field checked by a team of men who add names and correct any errors or make changes to bring the map up to date.

6. The corrected map is printed and distributed.

   a. The U.S.G.S. has published maps in 15 minute and 7½ minute series covering more than one-half of the United States.

   b. For the current map coverage in North Carolina, consult the free map index.

NATIONAL TOPOGRAPHIC MAP SERIES

SERIES	SCALE	1" EQUALS	STANDARD QUADRANGLE SIZE	QUADRANGLE AREA (Mi2)
7½"	1:24,000	2,000 ft	7½" x 7½"	49 - 70
15"	1:62,500	About 1 mi	15" x 15"	197 - 282
Alaska	1:63,360	Exactly 1 mi	15" x 20-36"	207 - 281
U. S.	1:250,000	Nearly 4 mi	1° x 2°	4,579 - 8,669
U. S.	1:1,000,000	About 16 mi	1° x 6°	73,724 - 102,759

NOTE: All maps published by the U.S.G.S. utilize polyconic projection.

D. Representing features on topographic maps:

   1. Man-made features and many naturally occurring features are shown on maps by means of symbols or colors.

   2. The U.S.G.S. has established a uniform series of symbols and colors. (See topographic maps pamphlet, Teacher's Packet of Geologic Materials.)

E. The shape of the land can be shown several ways.

   The shape of a land surface is principally a function of its relief. The relief of a land surface is the variation in height of the surface related to sealand.

   1. Relief may be shown several ways.

      a. Relief maps-miniature models of the land surface.
      b. Hatchures or short straight lines drawn in the direction that water would take in flowing down slope.
      c. Color-shading from green to dark brown describing high mountains.
      d. Contour lines-lines on a map joining all points on the surface having the same elevation.

2. How contour lines work (rules for contour lines):

   a. A contour line connects all points of the same elevation.
   b. Contour lines are shown for all elevations which are multiples of the contour interval.

      (1) Contour interval is the difference in elevation between lines. For example, when the contour interval equals ten feet, then contour lines are drawn at 0, 10, 20, 30 feet.
      (2) The contour interval used varies according to the size of the map and the topography of the area.
          (a) Normally, 10-20 foot intervals are used.
          (b) Steep mountains, 50-100 foot intervals.
          (c) Flat plains, 1-2 foot intervals.

   c. Index contours are heavier and darker than other contours. They are broken occasionally and the elevation is given.

   d. An x or BM (bench mark) indicates a point for which the exact elevation is known.

   e. Contour spacing is an indication of slope.

      (1) Wide spacing indicates a gentle slope.
      (2) Close spacing indicates a steep slope.

   f. Contour lines never cross. (They may appear to do so in the case of overhanging cliffs.)

   g. Contour lines never split. (They may appear to when they separate after running together along a cliff.)

   h. When crossing a stream valley, contours bend to form a V-shape pointing upstream.

   i. Contour lines form closed loops indicating a hill. (They may close off the map.)

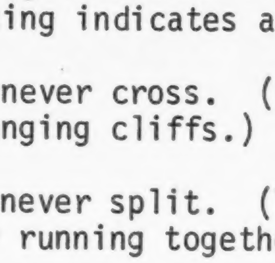
   j. Hatchured contours indicate a depression.

3. Places on a map may be located in four ways:

   a. By latitude and longitude designations.

   b. By direction and distance from a specified point.

   c. By rectangles.



LESSON 7, Introduction

THE ATMOSPHERE AS A HEAT ENGINE

Objectives:

1. To derive an understanding of the composition and structure of the atmosphere.
2. To understand the methods by which energy is introduced into the atmosphere and distributed.

References:

1. THE EARTH - SPACE SCIENCES, Chapter 18
2. FOCUS ON EARTH SCIENCE, Chapters 9 and 10
3. INVESTIGATING THE EARTH, Chapter 7

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D.C. Heath & Co., Atlanta), Chapters 26, 27, and 28
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 7
WEATHER AND CLIMATE IN NORTH CAROLINA. Agricultural Experiment Station, North Carolina State University, Raleigh
LOW TEMPERATURE PROBABILITIES IN NORTH CAROLINA. Agricultural Experiment Station, North Carolina State University, Raleigh

Activities:

1. Investigating radiant energy.
   ESCP Investigation 7-1 — Text 156
   Teacher's Manual 199-201

2. Investigating land and water temperatures.
   ESCP Investigation 7-10 — Text 172
   Teacher's Manual 209-212

3. The surface of the earth is unequally heated by solar radiation.

   Materials: screen wire
   slide projector
   large globe (12-16" diameter)

   Illuminate the globe by the light of the projector. Place the screen wire in the projector as if it were a slide. Focus so that the screen mesh may be seen clearly on the globe. Point out that the amount of light and heat passing through each square of the screen is the same. Note that where the light strikes the globe most directly, the squares are smallest and indicate the greatest concentration of heat and light. The larger squares at the two polar regions represent a low concentration of heat and light. Note that the same situation exists at sunrise and sunset on the globe.

4. Measuring the sun's power. Bell Telephone Company, Science Experiment No. 2, pp. 6-10.

LESSON 7

THE ATMOSPHERE AS A HEAT ENGINE

I. The Atmosphere

  A. The atmosphere is a mixture containing nitrogen (78%); oxygen (21%); other gases, principally CO_2 and argon (1%); and suspended water vapor, dust, and other particles.

  B. At least three cycles operate within the atmosphere that are vital to life.

    1. The Carbon Dioxide Cycle - maintains the balance between living things and gases in the air.

    2. The Nitrogen Cycle - nitrogen is converted by bacteria into compounds necessary to plant growth.

    3. The Hydrologic Cycle - cycle of water vapor, evaporation, condensation, precipitation.

  C. The atmosphere tends to be layered.

    1. The troposphere - the earth's surface layer, 5-11 miles thick.

      a. Within this layer, our weather phenomena occur.

      b. The temperature decreases with increasing altitude (3.5°/ 1,000 ft.)

    2. The stratosphere - from the upper troposphere boundary to about 30 miles out from the surface of the earth.

      a. There are no clouds, only some ice particles.

      b. The temperature tends to remain constant.

    3. The mesosphere - from 30 to about 55 miles out from the surface of the earth. The temperature drops with increasing altitude.

    4. The ionosphere - ionized layers above the mesosphere extending out to about 300 miles (atmosphere extremely thin).

II. The Sun's Energy Affects the Atmosphere

  A. 15% of the sun's energy is absorbed by the upper atmosphere.

  B. 42% of the sun's energy is reflected by the clouds and the atmosphere.

  C. 43% of the sun's energy penetrates to the surface of the earth.

    1. The amount of energy absorbed depends on the type of surface (albedo): snow (25%), water (60-96%), grass (80-90%), sand (75%), forest (95%), plowed fields (75-95%).

    2. The short wavelength energy absorbed by the earth is reradiated as

3. The atmosphere retards the passage of the heat energy into space and is heated as a result.

4. The result is a moderating effect on the earth's temperature known as the Greenhouse Effect.

D. The amount of heating that occurs at a given point on the earth's surface depends on four factors.

1. The amount of sunlight striking the surface.

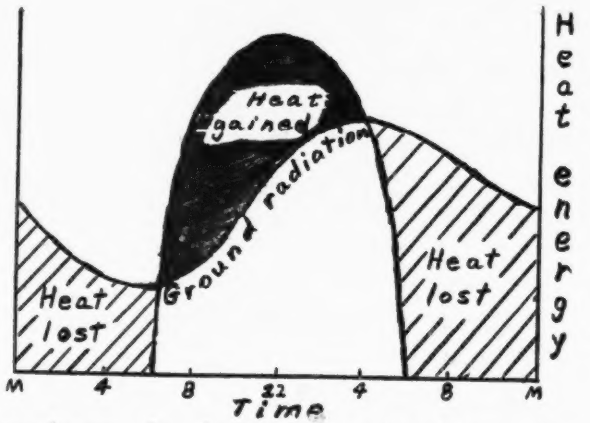
   a. Angle of incidence

   b. Exposure time

2. The amount of moisture in the air

3. Surface conditions

4. Night conditions



III. Movement in the Atmosphere is Caused by Heating and Cooling

A. Most initial air movement is caused by convection.

1. Convection occurs when air is heated causing it to expand; as it becomes less dense, it rises.

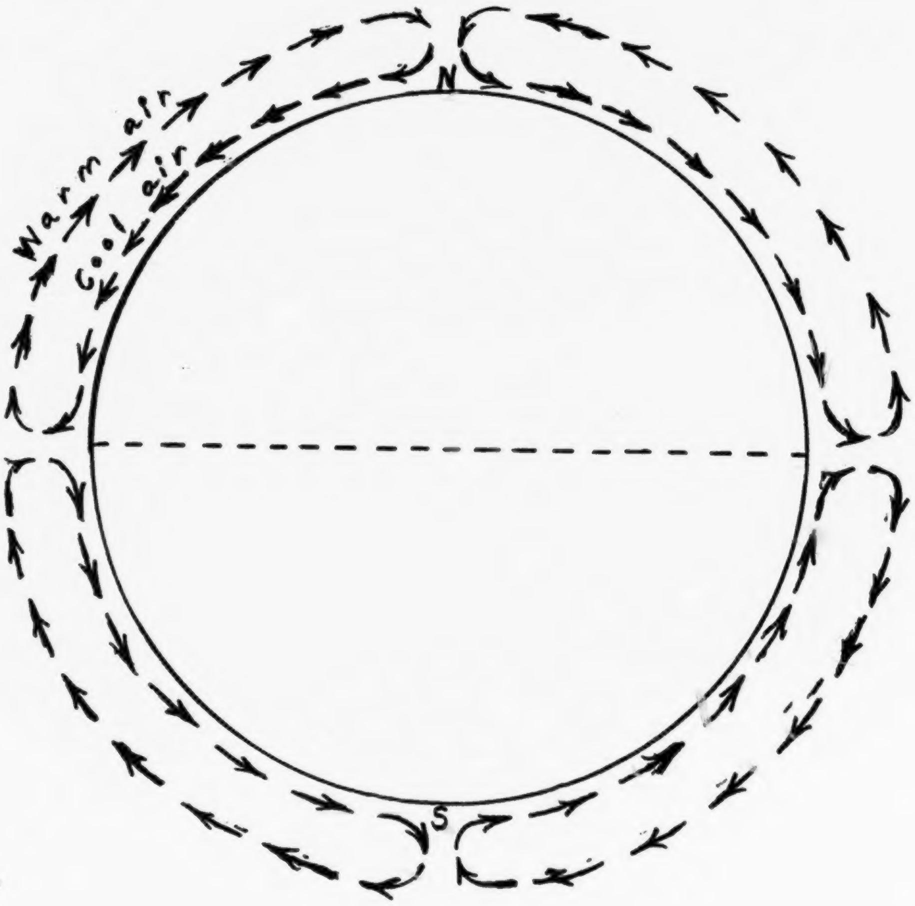
2. Most "local" breezes are due to convection currents.

3. The pressure of an air mass is usually related to its temperature.

B. The movement of air within the entire atmosphere is called Planetary Circulation.

1. This circulation is caused by the movement of warm air from the equator toward the poles, and cool air from the poles toward the equator.

(See illustration on next page.)


Warm air
Cool air
N
S

2. If the earth did not rotate, the result would be a simple series of convection cells.

LESSON 8, Introduction

ATMOSPHERIC CIRCULATION

Objectives:

1. To understand the coriolis effect.
2. To develop a concept of the organization and operation of atmospheric circulation.
3. To understand the mechanics involved in the development of local breezes.
4. To develop an understanding of air masses in terms of development and character.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 18.
2. FOCUS ON EARTH SCIENCE, Chapter 10.
3. INVESTIGATING THE EARTH, Chapter 7.

Special References:
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 8.
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapters 28 and 29.
WEATHER AND CLIMATE IN NORTH CAROLINA. Agricultural Experiment Station, N. C. State University, Raleigh, N. C.

Activities:

1. Coriolis Effect

   Thumbtack a piece of paper to a flat surface. Rotate the sheet of paper around the thumbtack and, at the same time, draw a line along a straight edge outward from the thumbtack. If you rotate the paper counterclockwise (the direction of rotation in the northern hemisphere) which way does the line curve? How about clockwise for the southern hemisphere?

2. Convection Currents (local breezes)

   Place a large beaker of water over a bunsen burner with a wing tip flame adapter. Heat the water slowly. Drop a small crystal of potassium permanganate close to the side of the beaker so that it falls directly over the heat source. What happens? Why? How can this be related to local breezes?
   (NOTE: THIS CAN BE USED EFFECTIVELY IN LESSONS 12 AND 28.)

3. Convection Currents

   Lower a lighted candle into a tall glass jar. The flame will die when the oxygen inside the jar is used up. Now insert a piece of cardboard into the jar to divide the space inside the jar (several holes should be cut in the cardboard below the height of the flame).

   Relight the candle and lower it into the jar. It will burn readily now as a current of cool air enters the jar on one side of the divider while the heated air expands and rises out on the other side. You might try blowing smoke into the air near the jar top to make the currents visible.

4. Coriolis and Wind Belts

   Construct the wind belt system on a slate globe. Referring to the diagram in Lesson 8, see if you can account for the wind direction in terms of coriolis effect (remember the earth revolves counterclockwise when viewed from the north pole).

5. Begin weather watch
   ESCP 8-9

Text 193
Teacher's Manual 232-237

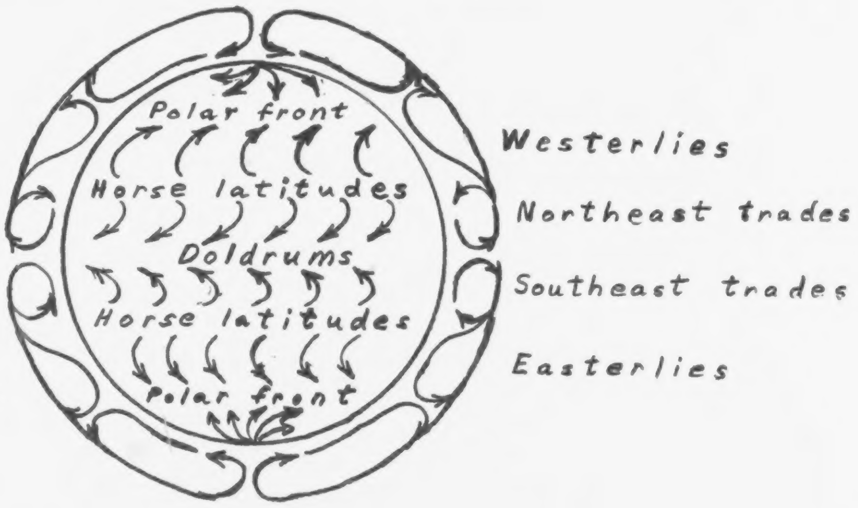
LESSON 8

ATMOSPHERIC CIRCULATION

I. The earth's rotation causes the winds to be deflected. The deflection is known as the coriolis effect.

A. The coriolis effect is the tendency of moving objects or winds to veer to the right in the northern hemisphere (left in the southern). This results from the earth's spinning out from under a moving object.

B. The coriolis effect results in the breaking of the convection cells into a series of wind belts that girdle the globe.



C. The Wind Belts

1. The Doldrums - a low pressure belt of rising air around the equator, a region of calms and weak, undependable winds.

2. The Trade Winds - (blow northeast in northern hemisphere). The air rising at the equator cools as it moves toward the poles. Around 30° latitude, it has cooled enough to begin to sink toward the earth. When this sinking air reaches the surface, it flows both toward and away from the poles. The portion flowing back toward the equator is known as the Trade Winds.

3. The Horse Latitudes - form the belt of sinking air at 30° latitude. In this region, the winds tend to be weak and unsteady.

4. The Westerlies - the winds moving from the Horse Latitudes toward the poles. This belt of winds blows between 40° and 60° latitude and tends to be much less steady than the Trade Winds.

5. The Subpolar Lows - belts of low pressure at about 60° latitude caused when the warmer Westerlies rise over the cooler and denser polar air.

6. The Polar Easterlies - extremely weak but relatively steady winds blowing away from the high pressure polar areas.

II. Local Winds are associated with the local heating and cooling of air near the earth's surface.

A. Land and Sea Breezes

1. Land heated to higher temperatures than water in the daytime.

a. Temperature difference develops.

b. Warm air over land rises; cool air flows in from sea.

c. Sea breeze is developed.

2. Land cools faster at night and the opposite effect creates a land breeze.

a. Air over the ocean rises because it is warmer.

b. Air over land moves in to fill the space left by the rising air.

B. Mountain and Valley Breezes

1. Mountains heat faster than the valleys during daylight.

a. Uneven heating sets up convection currents.

b. Valley breezes blow up the mountain slopes during the day.

2. At night, the mountains cool faster than the valleys, and the cool air flows down into the valley creating a mountain breeze.

III. Air masses - bodies of air covering millions of square miles of the earth's surface.

A. Chief characteristic of an air mass is that its temperature and humidity are fairly uniform at any particular altitude.

1. Weather associated with a given air mass is determined mainly by its temperature and moisture.

2. The temperature and moisture of an air mass do not change easily.

B. Origin of an air mass

1. An air mass is created when a body of air remains over a particular part of the earth for a long period of time.

2. These areas are high pressure centers.

a. Over oceans.

b. Over land.

C. Classification of air masses.

1. Air masses are classified according to source region.

- a. Cold polar source area (designated by P).
- b. Warm tropical source area (designated by T).
- c. Origin over sea (maritime - designated by m).
- d. Origin over land (continental - designated by c).
- e. Designation symbols thus: mT, cT, mP, cP.

2. A third letter is placed after the designation symbol to indicate whether the air mass is warmer or colder than the underlying surface it passes over.
    - a. Warm air mass (symbol w) may be cold, only warmer than the underlying surface.
    - b. Cold air mass (symbol k) may be warm but cooler than the underlying surface.

D. Air masses of North America

1. Polar Pacific (mP) cool and very moist air mass brings rain, snow in winter; rain, fog in summer.
2. Polar Atlantic (mP) air masses in winter bring cold overcast with light precipitation; in summer, cool air and fog.
3. Tropical continental (cT) brings clear, dry, very hot weather in summer only.
4. Tropical Gulf and Tropical Atlantic (mT) bring mild, cloudy winter weather and hot, humid summers with thundershowers.
5. Tropical Pacific (mT) brings cool, foggy weather in winter only.

E. Changes in air masses

1. Air masses move with the wind systems of the earth.
    - a. Polar air masses move southward with polar easterlies.
    - b. Tropical air masses move northeastward with the S.W. winds (westerlies).
2. Temperature and moisture of air mass may change.
    - a. Polar masses are warmed as they move southward; tropical masses are cooled as they move northward.
    - b. Maritime masses become drier over land and continental masses become more humid over water.

F. When two air masses with differing properties come in contact with one another, a front is developed.

1. If neither air mass is moving, the front tends to be stationary.

2. If one of the air masses is displacing another, the front takes on the character of the invading air mass. Therefore, moving fronts can be either warm (warm air replaces cold air locally) or cold (cold air replaces warm air locally).

3. If at some other stage of development the cold front overtakes the warm front, the result is an occluded front.

   a. If the air behind the cold front is colder than the air ahead of the warm front, the warm front is lifted and the occlusion is called the "cold front occlusion."

   b. If the air ahead of the warm front is colder than that behind the cold front, the cold front and the air behind it are pushed up the slope of the warm front. This is called a "warm front occlusion."

LESSON 9, Introduction

CLOUDS AND PRECIPITATION

Objectives:

1. To develop an understanding of humidity.
2. To create the concept of cloud formation as a process of cooling.
3. To understand the types of clouds and precipitation.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 18.
2. FOCUS ON EARTH SCIENCE, Chapter 10.
3. INVESTIGATING THE EARTH, Chapter 8.

Special References:
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 10.
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapter 31.

Activities:

1. Investigating evaporation
   ESCP 8-2 Text 181
   Teacher's Manual 223-225

2. Investigating cumulus cloud formation
   ESCP 8-12 Text 200
   Teacher's Manual 243-244

3. Continue weather watch

4. Investigation of dew point

   Even to the casual observer, it becomes evident that on a warm day cumulus clouds may appear in the sky. These clouds are formed from water vapor which is carried aloft by warm air rising from the ground. Because of release of pressure and expansion, this air is cooled as it rises. These adiabatic changes will be investigated later.

   When the air is cooled, the relative humidity is increased. If the air is cooled beyond a certain temperature, it can no longer contain all the moisture. The water vapor then begins to condense and form clouds. The temperature at which the water begins to condense is called the dew point. The dew point varies, depending on the relative humidity of the air.

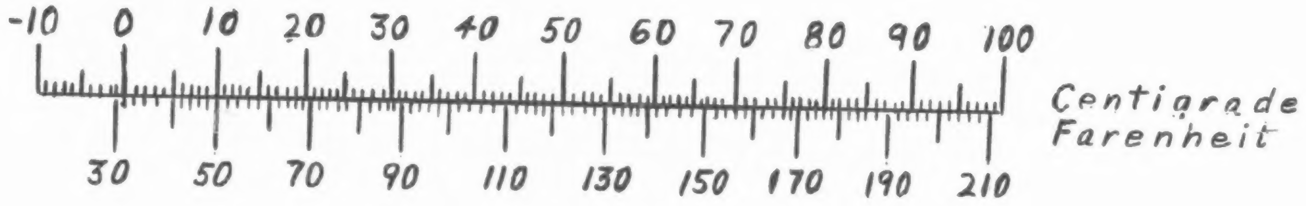
   At ground level when the temperature of the air reaches the dew point, the air becomes saturated (R.H. = 100%). Water vapor begins to condense on solid objects. We call this condensed water dew. If the dew point is below 32° F. (0° C.), frost forms. If we cool a metal can to the dew point of the air, water condenses on the surface, and we can determine the dew point of the air.

   Procedure:
   A shiny can, a thermometer, and some crushed ice are all that you need for determination of dew point. Fill the can about half full of water

put a thermometer in it (HOLD THE THERMOMETER). Add ice a little at a time. Stir gently with a pencil to melt the ice and cool the water evenly. As the water cools, the surface of the can cools at the same rate. The air around the can is also cooled. The temperature at which the condensation begins to form is called the dew point temperature. Keep watching the temperature. Assign one of the group to watch for the first sign of condensation on the can. If the condensation does not occur before the ice melts, add another piece of ice. DO NOT BREATHE ON THE CAN! Read the thermometer when the dew first appears and record the value. Remove any remaining ice and let the can warm up until the condensation disappears. The cooling and warming processes should be conducted slowly.

Repeat the process. The highest temperature at which condensation occurs is probably the best value for the dew point temperature.

Take a psychrometer reading both indoors and outdoors. Convert the psychrometer readings to dew point with the graph. (YOU MUST CONVERT THE PSYCHROMETER READINGS TO CENTIGRADE WITH THE CHART IN ORDER TO USE THE GRAPH.)



TEMPERATURE CONVERSION TABLE

DATA AND QUESTIONS

	TRIAL I		TRIAL II	
DEW POINT TEMPERATURE USING CAN	°F	°C	°F	°C
	INDOOR		OUTDOOR	
WET BULB TEMPERATURE				
DRY BULB TEMPERATURE				
DIFFERENCE BETWEEN WET AND DRY				
RELATIVE HUMIDITY %	%	%	%	%
DEW POINT FROM CHART				

QUESTIONS:

a. Why can the dew point be determined with the dew point can?

b. How do dew point temperatures indoors and outdoors compare?

c. How do the dew points taken with the sling psychrometer and the dew point can compare?

d. Why should the cooling process be conducted slowly?

e. Why are the indoor and outdoor temperatures different?

f. What is the relative humidity of the air just touching the surface of the can at the time concensation occurs?

5. Humidity and the sling psychrometer

The humidity is the amount of moisture in the air. Humidity is important for many reasons. The amount of moisture in the air can determine whether we are comfortable or not. For example, when the air is hot and humid, we feel very uncomfortable. We can measure the humidity in the air by means of an instrument called a sling psychrometer. A sling psychrometer measures relative humidity. Relative humidity is a measure of how nearly saturated the air is with water vapor.

Relative humidity is given by the expression:

$$\text{R.H.} = \frac{\text{Absolute humidity of air sample}}{\text{Capacity of the same air sample}} \times 100\%$$

The sling psychrometer consists of two identical glass thermometers mounted together. One thermometer has a small piece of cloth (called the wick) around the bulb. This is the wet-bulb thermometer.

QUESTIONS:

a. How could you construct a simple sling psychrometer?

   (1) Read the temperature of the two thermometers to the nearest degree. Both thermometers should read the same.

   (2) Wet the wick. Swing the psychrometer about two revolutions per second for about one minute. Stop swinging and read the wet-bulb temperature. Repeat the swinging for another minute and read again. When you get two consecutive readings that are the same, record this in the table as the wet-bulb reading.

b. Why is the wet-bulb temperature lower than the dry-bulb temperature?

c. Why does one sling the psychrometer before reading the wet-bulb temperature?

   (1) Read and record the dry-bulb temperature.

   (2) Repeat the entire process. Find the average wet-bulb temperature.

Table for Humidity Values:

	TRIAL I	TRIAL II	AVERAGE
Dry-bulb temperature			
Wet-bulb temperature			
Wet-dry difference			
Relative humidity			

d. Describe, in your own words, the meaning of wet-bulb and dry-bulb temperatures.

e. What is the relationship between the cooling of the wet-bulb thermometer and the water vapor content of the surrounding air?

f. How can the wet-bulb and the dry-bulb readings be converted to relative humidity?

g. What is done to make the readings of the wet and dry-bulb thermometers more accurate?

h. How are air temperature and relative humidity related?

i. What general statement might be made comparing the indoor and outdoor humidities?

j. Using the information you have obtained, find the dew point temperature on the chart in the lesson materials and find the height of cloud base.

6. Humidity problems (show your work, not just the answer.)

a. If the capacity of an air mass is 10.5 grains/meter^3, find the relative humidity if the air mass has an absolute humidity of 2.1 grains/meter^3.

b. If the capacity of an air mass at 60° F. is 13 grains/meter^3 and the relative humidity is found to be 40%, what is the absolute humidity?

Note: $\text{A.H.} = \frac{\text{R.H. X capacity}}{100\%} =$

c. For an air mass at 70° F., the absolute humidity is found to be 10 grains/meter^3. The capacity of the air mass at this temperature is 20 grains/meter^3. What is the relative humidity at 70° F.?

d. For the air mass in problem number (c), the temperature of the air mass is increased to 85° F., the capacity of the air mass is increased to 25 grains/meter^3. What would be the relative humidity at 85° F.?

e. The capacity of an air mass at 40° F. is 6.6 grains/meter^3, while the capacity of the same air mass is 18.5 grains/meter at 70° F. Find the relative humidities of the air mass at the two temperatures (40° and 70°) if the absolute humidity at both temperatures is 5.0 grains/meter^3.

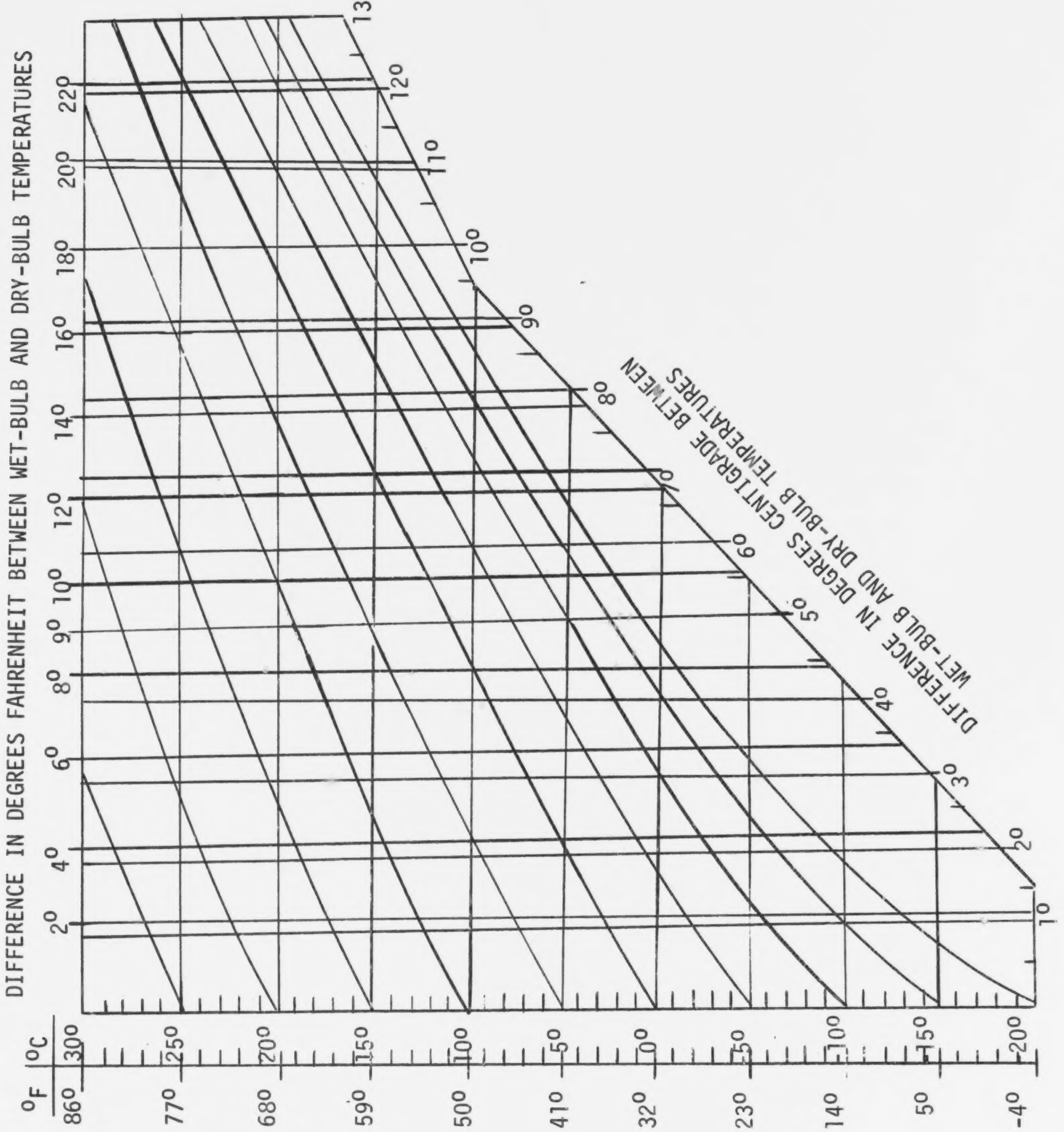
Complete the table below using the relative humidity chart.

Wet-Bulb Temperature (°F.)	Dry-Bulb Temperature (°F.)	Difference Between Wet and Dry-Bulb Temperatures (F.°)	Relative Humidity (%)
60°	70°		
25°	30°		
	70°	1°	
58°	68°		
70°	76°		
52°	52°		
65°	90°		
	65°		100%
	46°	13°	
		15°	44%

FINDING RELATIVE HUMIDITY IN PERCENT

Difference in Degrees Between Wet-bulb and Dry-bulb Thermometers

Air Temperature (reading of dry-bulb thermometer) in degrees Fahrenheit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
30°	89	78	68	57	47	37	27	17	8																					
32°	90	79	69	60	50	41	31	22	13	4																				
34°	90	81	72	62	53	44	35	27	18	9	1																			
36°	91	82	73	65	56	48	39	31	23	14	6																			
38°	91	83	75	67	59	51	43	35	27	19	12	4																		
40°	92	84	76	68	61	53	46	38	31	23	16	9	2																	
42°	92	85	77	70	62	55	48	41	34	28	21	14	7																	
44°	93	85	78	71	64	57	51	44	37	31	24	18	12	5																
46°	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4															
48°	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3														
50°	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2													
52°	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6													
54°	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9	5												
56°	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12	8	4											
58°	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15	11	7	3										
60°	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14	10	6	2									
62°	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17	13	9	6	2								
64°	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20	16	12	9	5	2							
66°	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15	11	8	5	1						
68°	95	90	85	81	76	72	67	63	59	55	51	47	48	39	35	31	28	24	21	17	14	11	8	4	1					
70°	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20	17	13	10	7	4	1				
72°	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22	19	16	13	10	7	4	1			
74°	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1		
76°	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26	23	20	17	14	12	9	6	4	1	
78°	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28	25	22	19	16	14	11	9	6	4	1
80°	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29	27	24	21	18	16	13	11	8	6	4
82°	96	91	87	83	79	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31	28	25	23	20	18	15	13	10	8	6
84°	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32	30	27	25	22	20	17	15	12	10	8
86°	96	92	88	84	80	77	73	70	66	63	60	57	54	51	48	45	42	39	37	34	31	29	26	24	21	19	17	14	12	10
88°	96	92	88	85	81	78	74	71	[illegible]	64	61	58	55	52	49	46	43	41	38	35	33	30	28	25	23	21	18	16	14	12
90°	96	92	88	85	81	78	74	71	68	64	61	58	56	53	50	47	44	42	39	37	34	32	29	27	24	22	20	18	16	14



DRY-BULB TEMPERATURE AND DEW POINT
(Fahrenheit and Centigrade Scales)

LESSON 9

CLOUDS AND PRECIPITATION

I. Atmospheric moisture enters the air through evaporation.

A. The sea is the principal source of atmospheric moisture.

B. The cycle of evaporation, condensation, precipitation, etc., is called the Hydrologic Cycle.

II. Measurement of atmospheric moisture.

A. The content of water vapor in the air is loosely referred to as humidity.

1. ABSOLUTE HUMIDITY is the mass of water vapor actually contained in a certain volume of air.

a. The grain (.002 oz.) is a unit commonly used to measure humidity.

b. Humidity is measured in grains/meter^3 (absolute humidity).

2. RELATIVE HUMIDITY refers to the amount of moisture in a given volume of air compared to its actual capacity at that specific temperature.

a. Relative humidity is expressed as per cent.

b. $\text{Relative Humidity} = \frac{\text{Absolute Humidity}}{\text{Capacity of same volume}} \times 100\%$

c. CAPACITY depends on temperature (warm air holds more moisture or has a higher capacity) and pressure (higher pressure reduces capacity).

3. An instrument used to measure humidity is a hygrometer.

a. Wet and dry-bulb thermometers--psychrometer.

(1) Cooling of the wet-bulb thermometer is directly related to the rate of evaporation.
(2) Water molecules evaporate more readily into drier air.
(3) The rate of evaporation is proportional to the relative humidity of the surrounding air. (see Chart 9-1)

b. The hair hygrometer is based on the principle that moist hair stretches.

III. Water must become a vapor before it can enter the air. It must become a solid or liquid before it can leave the air.

A. As air is cooled, it reaches a point where it holds all the water vapor it can hold at that temperature.

1. It is said to be saturated.

2. Absolute humidity = capacity.
3. Relative humidity = 100%.

B. The temperature at which water vapor in the air begins to condense is called the dew point. (see Chart 9-2)

1. Dew forms on objects at and below this temperature.
2. If the dew point is below 32° F., frost occurs.

IV. When a gas (air) expands or contracts, it changes temperature. These changes are called ADIABATIC CHANGES.

A. Molecules in a gas absorb heat energy by impact with other molecules as they move about in space.

B. When a gas is under a given pressure, there are a relatively fixed number of molecules moving about in any given volume.

C. If a body of air (gas) is forced up, the pressure on the gas is lessened, and the molecules move apart (the gas expands). In a space equal to the beginning volume, there will then be fewer molecules and, thus, the average temperature will be lower. The energy of any given molecule is the same, but the reduction in number per unit volume has reduced the average temperature.

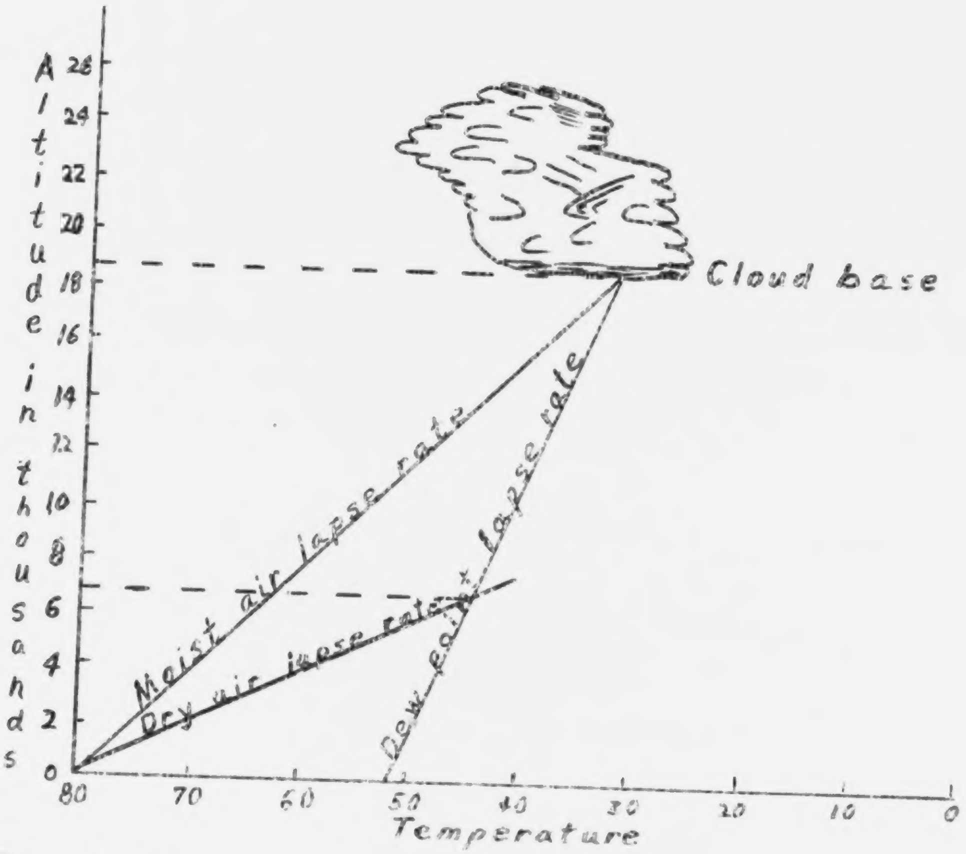
D. Most condensation in the atmosphere results from an adiabatic cooling of rising air masses.

E. Relatively dry air when lifted cools at a rate of 5.5° F./1000 ft. (10° C./Kilometer) of altitude.

F. The dew point temperature also varies with pressure. The dew point temperature decreases about 1° F./1000 ft. (1.7° C./Kilometer).

G. The dew point is therefore approached at 4.5° F./1000 ft. (8.3° C./Kilometer).

H. When air reaches the altitude at which the dew point temperature is reached, it condenses about dust, salt, or other particles forming small droplets which make up a cloud.



V. Cloud Formation

   A. Cooling and condensation caused by adiabatic changes.

   B. Condensation nuclei are also necessary.

      1. Droplets form around these nuclei.

      2. These may be dust, smoke, or salt particles.

      3. The most common are NaCl and SO_2.

VI. Cloud Types

   A. Classification of clouds: In 1803, Luke Howare, an Englishman, proposed a system of cloud classification based on how clouds look from the ground.

      1. Four families - high, medium, low, and vertical.

      2. Shapes of clouds are determined by their manner of formation.

         a. Air movement horizontal - STRATIFORM.

         b. Vertical movements form great billowy mounds - CUMULIFORM.

      3. Three simple names - cumulus, stratus, cirrus.

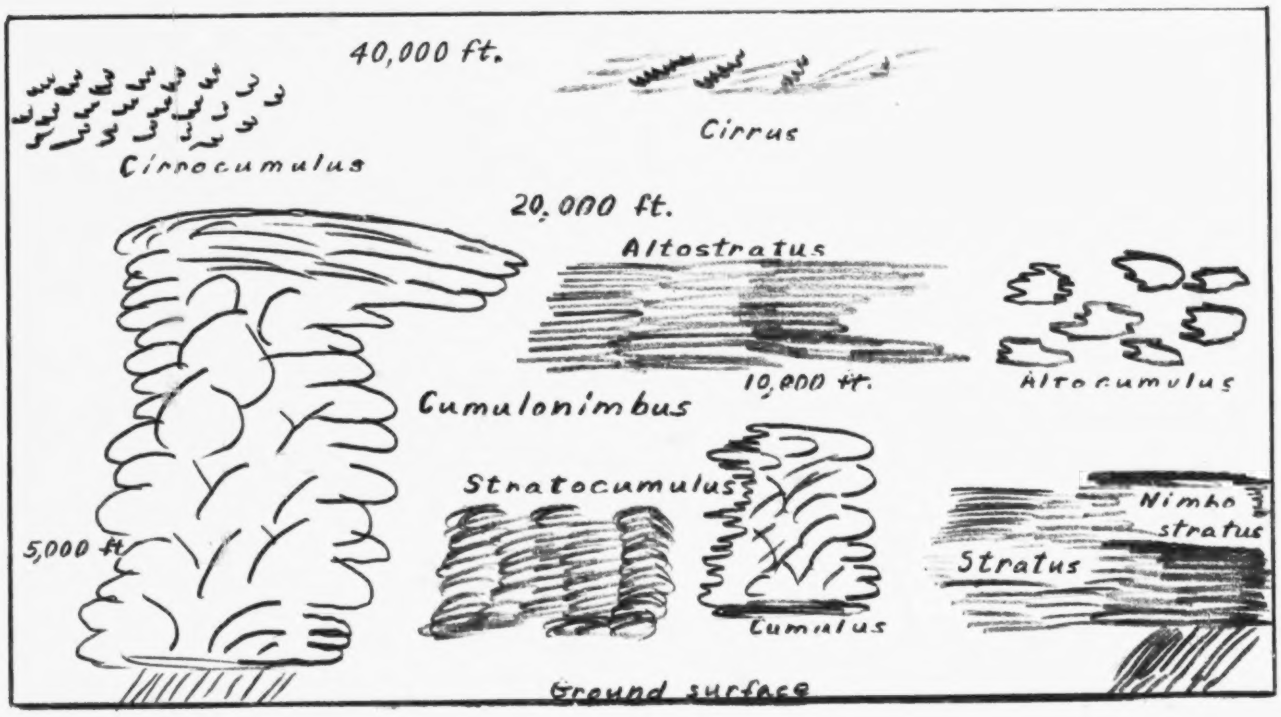
  a. CUMULUS - individual clouds, appear as giant cauliflowers.

  b. STRATUS - form in flat layers.

  c. CIRRUS - high altitude clouds composed of tiny ice crystals. They have a silken, wispy, or feathery appearance.

4. Prefixes may be added (ALTO - high; NIMBO - rain).

5. These basic names may be combined (example: stratocumulus).


40,000 ft.
Cirrocumulus
Cirrus
20,000 ft.
Altostratus
Altocumulus
Cumulonimbus
10,000 ft.
Stratocumulus
Nimbo stratus
Stratus
5,000 ft
Cumulus
Ground surface

B. Fog - air close to ground level cools below the dew point forming fog.

1. Cooling of the earth at night - GROUND FOG.

2. Moist warm air from over water moves across the cooler land surface - ADVECTION FOG.

3. ADIABATIC cooling of air as it sweeps up rising land slopes - UPSLOPE FOG.

VII. Precipitation

A. Cloud droplets are very small (1/2500 inch in diameter). In order to fall, they must grow to at least 1/125 inch in diameter.

B. There are two ways in which cloud droplets grow large enough to become precipitation. The process is called coalescence.

1. Condensation nuclei are of different sizes, thus the droplets are different sizes--larger droplets drift downward, collide, and combine with smaller droplets and grow in size.

2. When the air temperature is lower than 32° F. or 0° C., the water vapor condensing forms ice crystals. These ice crystals, in turn, serve as condensation nuclei. Further condensation causes these crystals to grow, forming snowflakes. Usually, the air temperatures immediately above the surface of the earth are warm enough to cause this ice to melt before it reaches the surface.

C. Types of Precipitation

1. DRIZZLE - extremely fine drops close together falling very slowly.
2. RAIN - larger drops.
3. SNOW - branched **hexagonal** crystals falling as ice.
4. SLEET - rain falling from warmer layer into cooler air below and freezing.
5. FREEZING RAIN - supercooled rain freezing at or near the surface forming ice or glaze. Severe conditions are called an ice storm.
6. HAIL - forms in thunderstorms. Ice accumulates around a center as updrafts cause a buffeting about of these ice balls from warmer moist layers of cloud to colder upper layers. The weight of the accumulated ice finally causes these balls of ice to fall.

LESSON 10, Introduction

FORECASTING THE WEATHER

Objectives:

1. To understand the types of data required for forecasting weather and the methods used to acquire such data.
2. To understand how a weather map is constructed and is read.

References:

1. FOCUS ON EARTH SCIENCE, Chapter 10.
2. INVESTIGATING THE EARTH, Chapter 8.

Special References:
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 8.
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapter 27.

Activities:

1. Investigating weather maps
   ESCP Investigation 8-13 Text 200

   NOTE: This investigation should be completed after the discussion of cyclonic storms in Lesson 11.

2. Laboratory exercise (station models and weather maps) as follows on the next page

   NOTE: This exercise should be begun this time and fronts should be drawn following Lesson 11.

3. Continue weather watch

Laboratory Exercise
Station Models and Weather Maps

Weather stations all over the United States collect and record data. This data is recorded on weather maps and from this information, weather forecasting is done. The information is placed on the map in an agreed arrangement around a circle on the map. The circle represents the station for which the data was taken. The observations normally plotted include: atmospheric pressure, air temperature, dew point temperature, wind speed and direction, cloud types, portion of the sky covered by clouds, visibility, and type of weather (rain, snow, etc.). This arrangement of data is called a STATION MODEL.

Procedure:

1. Plot the data around each station model example below. Then plot the given data for each of the stations on the accompanying map. Use information on the back of a standard Sunday issue of The Environmental Science Services Administration (ESSA) daily weather map.

2. Draw isobars for each 4-millibar change in pressure (1000, 1004, 1008, etc.). Omit the 9 or 10 and write only the last three figures of the of the pressure. Examples: Pressure
   1019.3 - 193
   987.7 - 877
   (Hint: Draw isobars much like you would draw contour lines for a topographic map.)

3. Locate and draw in the fronts. Fronts are located by a kink or a change in direction of the isobars. Shifts in wind direction and changes in temperature indicate positions of the fronts.

Data for Example Station Models

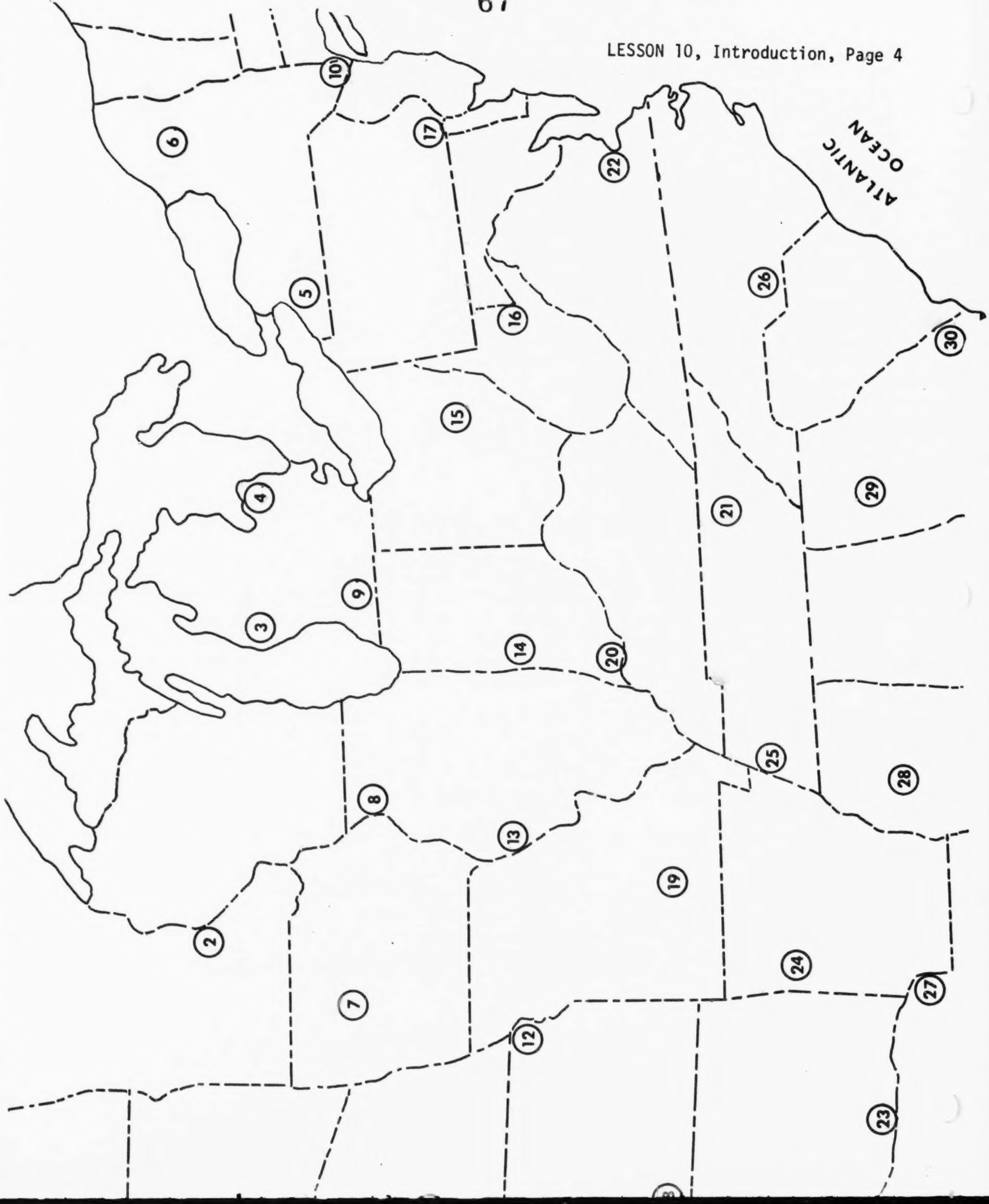
	I	II	III
Wind direction	N	E	SW
Wind speed	5	30	16
Cloud coverage	clear	overcast	scattered
Temperature	80°	26°	71°
Current weather	clear	snow	drizzle
Dew point	53°	26°	60°
Pressure change	-2.0	-	-.4
Past weather	clear	snow	thunderstorm
Amt. precipitation	-	.2	.9
Pressure	1020.1	1001.7	1013.7

STATION I

STATION II

STATION III

STATION	WIND DIRECTION	WIND SPEED (mph)	CLOUD COVER	TEMP. (°F.)	VISIBILITY	CURRENT WEATHER	DEW POINT (°F.)	PRESSURE (mb)	PRES. CHANGE (mb)	PAST WEATHER	AMOUNT OF PPT.
1	-	-	-	42	20	clear	32	1006.0	+ .9	-	-
2	N	5	-	43	15	clear	35	998.5	+ .3	rain	.2
3	-	-	overcast	55	0	drizzle	54	988.9	-2.4	-	.2
4	SSE	20	overcast	60	1	drizzle	58	994.1	-1.8	-	.1
5	SE	20	5/10	57	2	clear	55	999.6	-2.0	-	-
6	SSE	5	2/10	55	4	clear	50	1004.9	-1.0	-	-
7	N	5	-	41	12	clear	34	1000.0	+ .4	drizzle	.1
8	N	20	5/10	40	8	clear	36	994.8	+ .1	rain	.3
9	W	20	overcast	61	½	rain, fog	61	990.0	-1.7	-	.1
10	S	10	-	60	10	clear	55	1008.0	-	-	-
11	N	5	-	41	20	clear	32	1007.0	+1.1	-	-
12	NNW	10	5/10	39	8	-	34	1002.2	+ .7	-	.6
13	NW	15	5/10	39	6	-	35	997.0	+ .2	thunderstorm	.2
14	W	15	overcast	64	4	thunderstorm	60	995.8	- .9	-	.1
15	SW	15	5/10	63	20	-	48	998.0	-2.0	-	-
16	SSW	5	5/10	63	20	-	48	1000.9	- .8	-	-
17	SSE	10	5/10	59	6	-	56	1004.9	- .6	-	-
18	N	5	5/10	44	20	-	35	1008.0	+2.1	rain	.4
19	NW	25	overcast	40	3	thunderstorm	36	999.1	+ .1	thunderstorm	.3
20	WSW	10	overcast	64	½	drizzle	57	998.2	-1.1	-	T
21	WSW	5	3/10	66	20	-	57	1002.0	-1.4	-	-
22	SW	5	3/10	64	7	-	58	1005.8	- .1	-	-
23	N	25	overcast	43	4	thunderstorm	39	1007.1	+ .1	thunderstorm	.5
24	NW	30	overcast	41	4	thunderstorm	36	1002.9	+ .2	thunderstorm	.6
25	WSW	15	overcast	64	1	rain	59	1001.0	-	-	-
26	-	-	-	67	20	-	58	1005.8	- .7	-	-
27	W	15	5/10	65	7	-	54	1008.1	- .8	-	-
28	W	5	2/10	64	10	-	54	1006.0	- .9	-	-
29	SSW	10	-	70	20	-	56	1006.0	- .1	-	-
30	W	5	-	69	20	-	56	1011.0	- .7	-	-


ATLANTIC OCEAN
2
3
4
5
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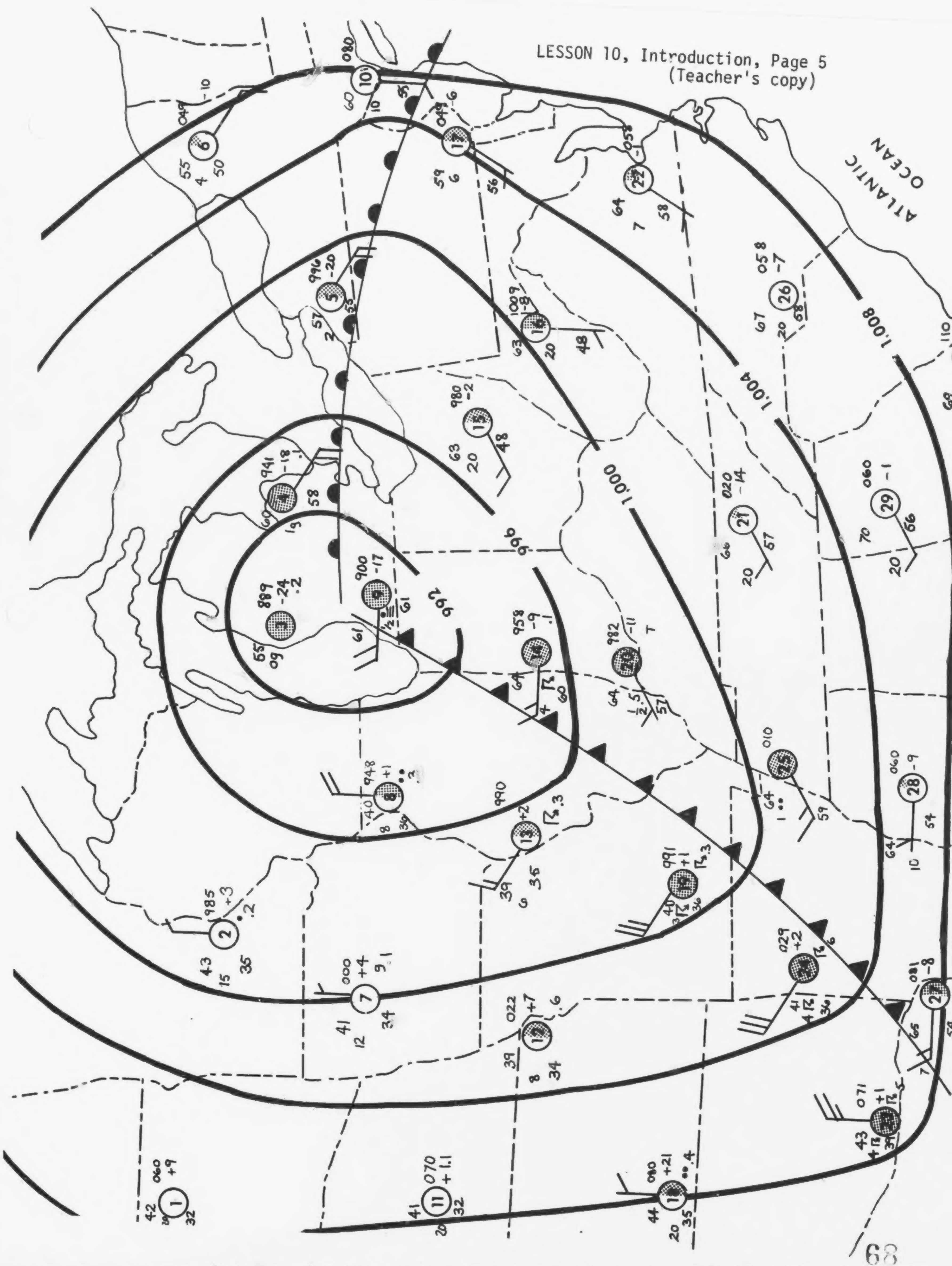

ATLANTIC OCEAN
1,008
1,004
1,000
996
992
990

LESSON 10

FORECASTING THE WEATHER

I. Meteorology is the branch of science involved in forecasting weather.

  A. Because weather moves across the United States, it is necessary to have information from a number of locations.

    1. The U. S. Weather Bureau maintains

      a. 315 offices serving 297 communities.

      b. 3,500 part-time stations.

      c. Many other sources.

    2. Each year, more than 58,000 instruments are read in the process of gathering information.

  B. To interpret the mass of information, the weather bureau uses maps.

    1. The information gathered at each station is displayed on the map as part of a "station symbol."

    2. Once displayed on the map, the information is used to draw general, overall weather patterns and determine forecasts.

II. Data Acquisition (Note: Only portions of the total information acquired will be discussed due to space and time limitations.)

  A. Data is normally gathered at each station on the following:

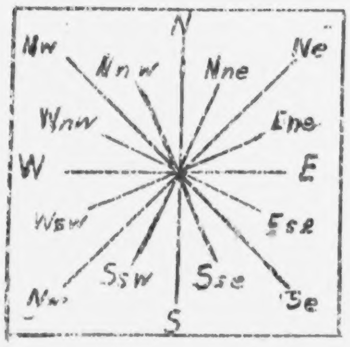
    1. Wind direction
    2. Wind speed
    3. Cloud coverage
    4. Temperature
    5. Dew point
    6. Barometric pressure
    7. Current weather
    8. Past weather
    9. Precipitation amount
    10. Cloud type

  B. Special instruments are used to collect this information.

    1. Wind direction is determined with a wind vane.

      a. Wind is given according to the direction from which it is blowing.

      b. The direction can be given in degrees (0^{o} - 360^{o}) clockwise from the north or in points of the compass.



2. Wind Speed is measured by an anemometer. The most common anemometer consists of a set of three small cups which catch the wind. The cups are connected to a shaft which turns as the cups are blown around. The rate of rotation which is shown on a dial is proportional to the wind speed. Wind speed is normally recorded in knots (nautical miles per hour).

3. Temperature is recorded in degrees celsius (farenheit is used only for public weather broadcasts).

   a. Maximum and minimum temperatures are recorded by a special type thermometer.

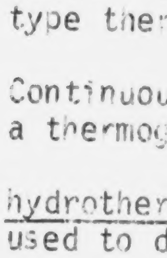
   b. Continuous temperature records are made by a device called a thermograph.

4. The hydrothermograph, the sling psychrometer, or the hygrometer are used to determine the dew point.

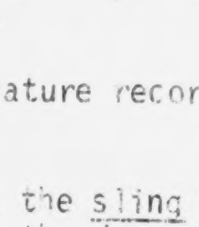
5. Barometers, both aneroid and mercurial, are used to determine station pressure. A barograph is used to keep a continuous record of pressure. All pressures are reduced to sea level or some reference plane before they are reported.

   a. Standard sea level pressure on the mercurial barometer is equivalent to a column of mercury 29.92 inches or 760 millimeters high. Another unit used by meteorologists is the millibar (mb) which is a unit of air pressure equal to a force of 1,000 dynes per square centimeter.

      (1) One inch of mercury is equal to about 33.9 mb (0.01 inch = .339 mb).
      (2) Standard sea level pressure is 1013.2 mb.



Mercurial



Aneroid

6. Precipitation is recorded by several types of gauges.

C. Special sensing instruments include

1. The radiosonde - a set of small instruments sent aloft by a balloon.

2. Radar - gives precise location and extent of storms.

a. Tornadoes can be discovered and tracked.

b. Wind currents aloft can be determined by tracking balloons.

3. Weather satellites show cloud cover and give a picture of atmospheric conditions over the earth.

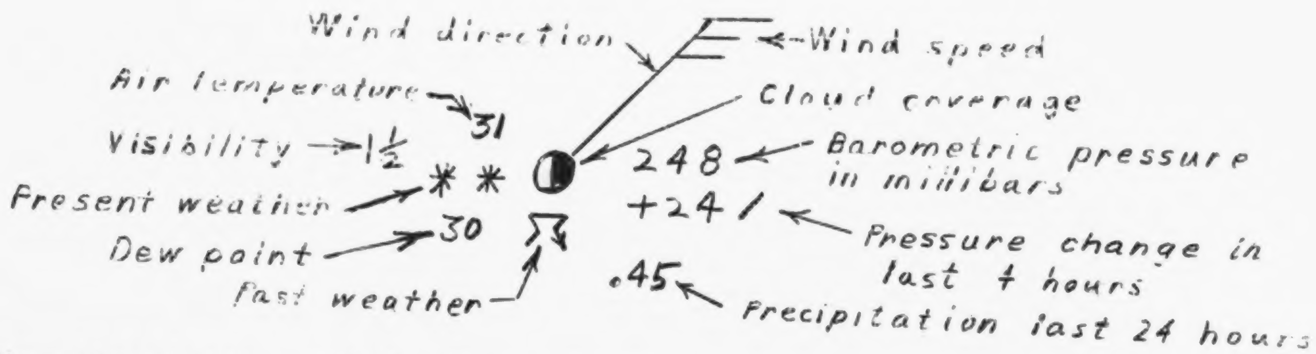
III. Data Display

A. Once data has been collected at a station, it is sent to the National Meteorological Center in Suitland, Maryland, and to other selected military and civilian weather stations by teletypewriter.

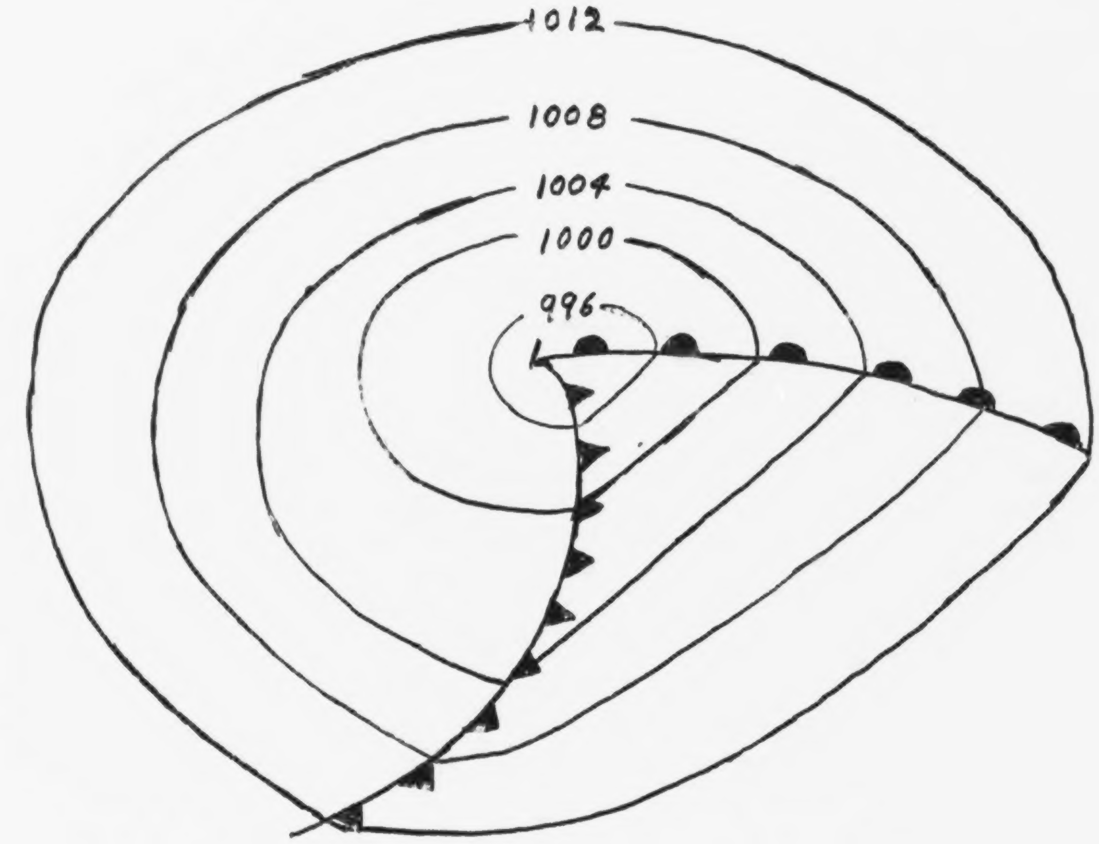
B. At Suitland, the teletype data is put on a map either by hand or by computer.

C. Weather maps are prepared from data transmitted by all stations eight times a day (1:00 a.m., 4:00 a.m., 7:00 a.m., 10:00 a.m., 1:00 p.m., 4:00 p.m., 7:00 p.m., and 10:00 p.m. EST).

D. Station weather is shown on a map as a station symbol.


Wind direction
Wind speed
Air temperature
31
Cloud coverage
Visibility
1½
248
Barometric pressure in millibars
Present weather
* *
+24 /
Pressure change in last 4 hours
30
Dew point
Past weather
.45
Precipitation last 24 hours

E. After the station symbols have been recorded on the map, lines are drawn connecting points of equal pressure. Usually, these isobars (contours of equal pressure) are drawn at four millibar intervals.



F. The location, shape, and spacing of isobars indicate the shape, size, and motion of storms and other weather systems.

1. Isobars mark the position of fronts as well as high and low pressure regions.

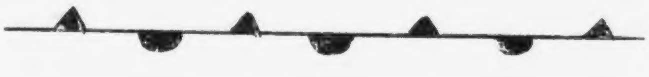
2. The spacing of isobars indicates the slope of the pressure gradient and thus the wind direction and speed.

    a. Closely spaced isobars mean rapid pressure change and higher wind speeds.

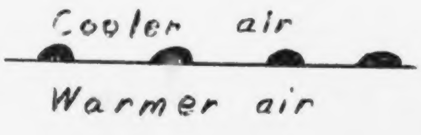
    b. Widely spaced isobars generally mean slower wind speeds.

3. Barometric changes plus the associated weather indicate the position of fronts.

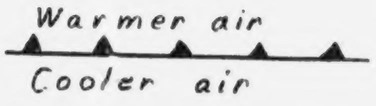
    a. Stationary fronts are shown by the symbol shown here -



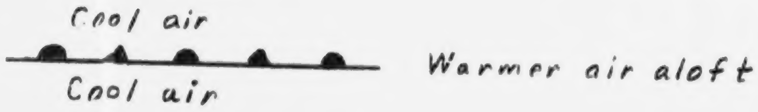
    b. Warm fronts -



c. Cold fronts -



d. Occluded fronts -



IV. Forecasts

A. Early people observed the weather (many because it determined or influenced their livelihood) and attempted to forecast the weather.

1. Early people developed many proverbs and myths.

2. Some make sense; others are superstitions.

3. Some legends, proverbs, myths, and superstitions:

a. "Mackeral scales and mare's tails make lofty ships carry low sails."

b. "Red sky at night, sailors delight. Red sky in the morning, sailors take warning."

c. Smoke rises indicating poor weather.

d. Halo around the moon--poor weather.

e. Ground Hog's Day.

B. Weather forecasting today involves scientific principles.

1. Forecasters keep up with movements in the 5 billion cubic miles of atmosphere surrounding the earth.

a. Basic tool--the weather map.

b. Forecaster predicts formation of weather systems from this map.

2. Principles used in weather forecasting.

a. Upper air in the middle latitudes moves in a generally easterly direction; low level weather is carried along.

b. Low pressure systems move toward areas of falling pressure and away from rising pressure. Speed of movement depends on pressure differences.

c. Steepness of the slope of the front determines whether the lifting of air can produce condensation, cloudiness, or precipitation.

d. As a rule, poor weather usually accompanies a low pressure system.

3. Forecasts are made for all areas of the United States four times daily and are released at 5:00 a.m., 11:00 a.m., 5:00 p.m., and 10:00 p.m. (local time).

   a. Forecasts basically cover 48-hour periods.

   b. Extended outlooks are also issued -

      (1) Each day extended outlooks for the third, fourth, and fifth days are issued.
      (2) Twice monthly, a 30-day outlook is issued giving a broad outline of expected precipitation and temperature ranges.

LESSON 11, Introduction

CYCLONIC STORMS

Objectives:

1. To develop an understanding of frontal weather.
2. To develop an understanding of air flow about and the development of pressure centers.
3. To understand the causes, development, and life cycle of a cyclonic storm.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 18.
2. FOCUS ON EARTH SCIENCE, Chapter 10.
3. INVESTIGATING THE EARTH, Chapter 8.

Special References:
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 11.
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapters 28, 29, and 30.

Special Supplementary References in Paperback:
Batten, Louis J., THE THUNDERSTORM, (Signet).
Batten, Louis J., THE NATURE OF VIOLENT STORMS, (Doubleday-Anchor), (Science Study Series S-18).
Edinger, James G., WATCHING FOR THE WIND, (Doubleday-Anchor), (Science Study Series S-49).
Batten, Louis J., RADAR OBSERVES THE WEATHER, (Doubleday-Anchor), (Science Study Series S-24).
Battan, Louis J., THE UNCLEAN SKY, (Doubleday-Anchor), (Science Study Series S-46).

Activities:

1. Complete investigating weather maps
   ESCP Investigation 8-13

2. Complete exercise on station models and weather maps

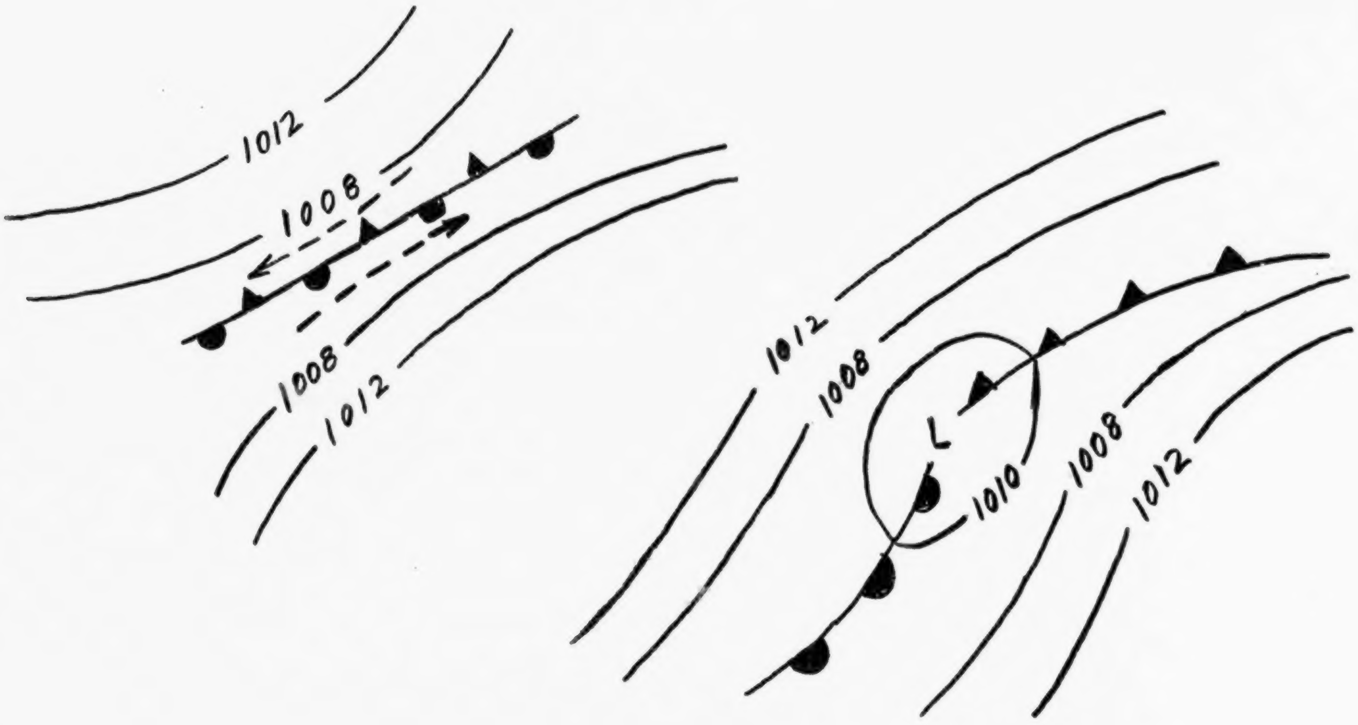
3. Discuss weather watch in light of Lesson 11 and complete

LESSON 11

CYCLONIC STORMS

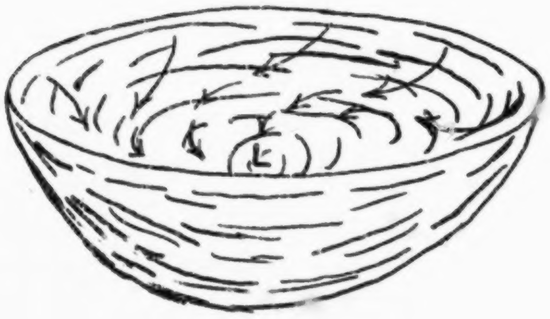
I. The Development of Cyclonic Storms

A. Storm centers are usually formed by bulges of cold air along a stationary front which develop into a low pressure area. The center of low pressure is developed because the cooler air pushes under the warmer air causing it to rise. Since air requires an input of heat energy to cause expansion and the resulting lifting effect, the air must contain some moisture. The initial lifting by the cooler air mass causes adiabatic cooling and the resulting condensation of moisture results in a liberation of heat energy. The liberation of heat energy results in additional expansion causing the air mass to become less dense than the surrounding air and therefore the air mass continues to rise.

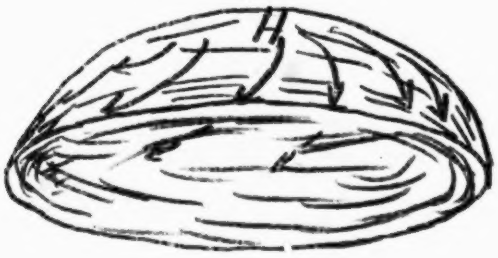


1. As the center of low pressure develops, winds begin to blow down the pressure gradient toward the newly developed center of lower pressure.

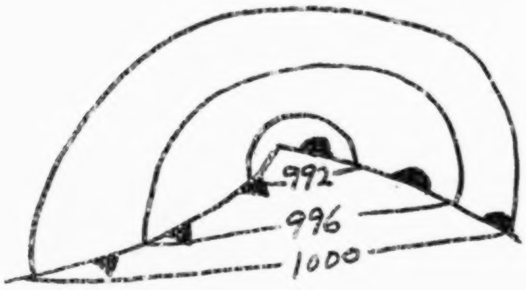
2. Because of the coriolis effect, the winds blowing toward the center of low pressure are turned to the right in the Northern hemisphere and as a result blow counterclockwise about the center



Conversely winds blowing away from a center of high pressure are turned to the right and blow clockwise about the center.



3. As the pressure drops and the wind increases, the air masses move into one another and fronts develop.

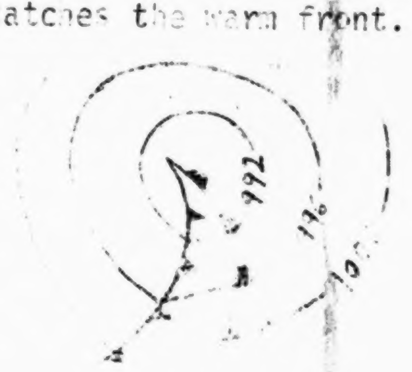


a. The warm front where the warm air is replacing the cooler air is generally a gently sloping surface characterized by clouds as shown below.

This type of front is characterized by slow, steady rains lasting from 12 to 24 hours.

b. The cold front where the cooler air is replacing the warmer air is more steeply sloping and is characterized by shorter, but more violent, showers or thunderstorms.

Generally the cold front plunges ahead about twice as fast as the warm front so that eventually the cold front overtakes and catches the warm front.



c. As the cold front catches the warm front, the warm air mass is pushed up and an occlusion develops.

When the occlusion is complete and the warm air is lifted, there is no further heat energy available to maintain the low pressure center and the storm center dissipates.

B. Because of the prevailing westerlies storm systems follow a more or less Northeast tract across the United States.

1. Weather systems usually move eastward at a rate of between 300 and 500 miles per day.

2. Cyclonic storms normally last from 5 to 6 days.

C. Assuming that weather conditions will be consistent (Many other factors such as terrain, other weather systems, or upper air movement can cause changes.) weather predictions can be made by tracking the storm or front and extending the track for the storm's estimated 24-hour movement.

D. Severe Storms are the best known, most feared, and least understood of all weather phenomena. They include three well-known types--thunderstorms, tornadoes, and hurricanes.

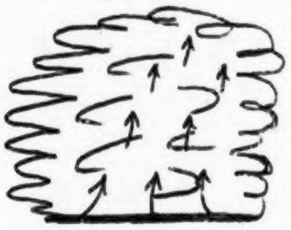
1. Thunderstorms are severe local storms accompanied by lightning and thunder.

a. Thunderstorms undergo three stages of development:

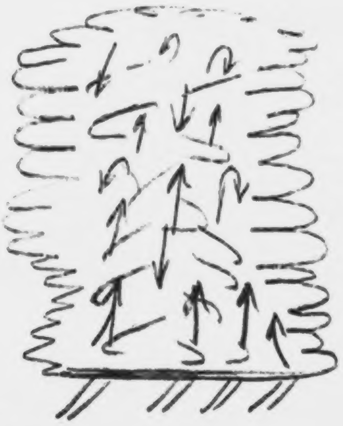
(1) These have arbitrarily been labeled:

(a) Cumulus stage.
(b) The mature stage
(c) The final stage.

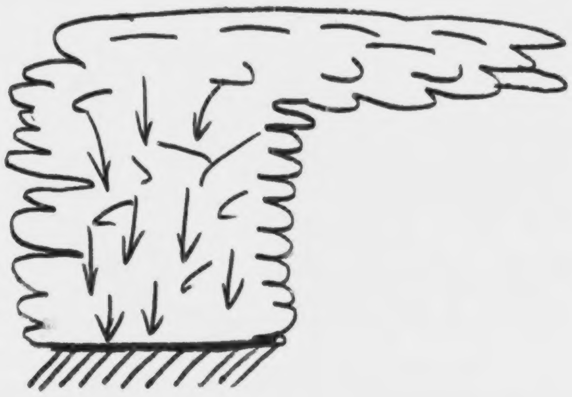
b. The cumulus stage occurs usually in warm, humid, unstable air. Convection cells develop due to local heating and cooling. These cells develop into cumulus clouds and rise to heights approaching 25,000 feet.



c. The mature stage begins when the air cools (due to precipitation) and ceases to rise. This cooling causes downdrafts to develop and precipitation occurs at the ground. At this stage the storm is most violent and there are both up and down drafts in the clouds.



d. The final stage occurs when all updrafts have disappeared and the cloud is one great mass of sinking air (being warmed adiabatically). Precipitation ceases and winds aloft dissipate the cloud.



II. Lightning is produced as an accumulation of charges within the cloud.

A. Top of cloud becomes positively charged, possibly because of friction of raindrops removing electrons.

B. Electrons accumulate in the bottom of the cloud.

C. Central region also negative.

D. After rain begins, a small center of positive charges develops near the cloud base.

E. As charges increase a voltage difference develops.

  1. Lightning occurs when this voltage difference becomes large enough.

  2. May be 10,000 volts/cm.

  3. Strike neutralizes the charges.

F. By studying lightning, it can be seen that lightning occurs in a series of steps.

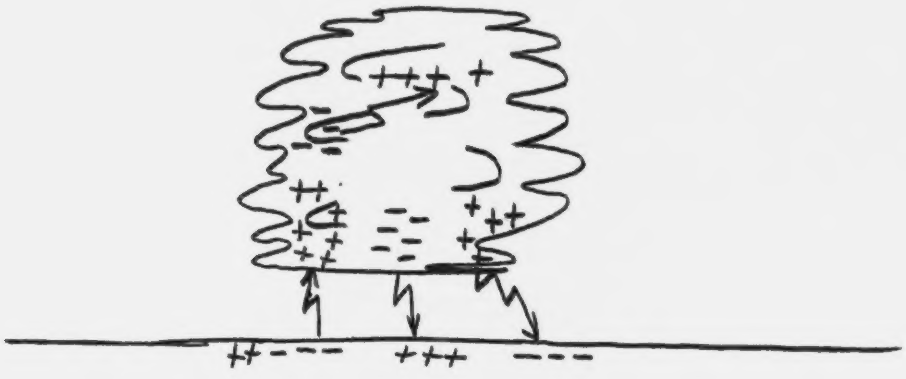
  1. Detected by high speed photography.

  2. First a "feeler" reaches out in steps of about 200 feet at a time.

  3. Then there is an electrical surge, followed immediately by a return stroke.

  4. Time - 1/100 of a second.

  5. Many strokes move along this channel in rapid succession. (40 have been observed in a second.)



G. Because of the expansion of air by lightning, an intense sound wave is produced which we call thunder.

  1. Light travels faster than sound.

  2. The distance of a lightning strike from an observer, in miles, can be approximated by dividing the seconds between the sighting of the flash and the hearing of the sound by 5.

  3. Rumbling caused by unequal time for sound to reach the observer.

III. Hurricanes are low pressure storms bearing some resemblance to the middle latitude cyclones.

  A. Hurricanes occur in tropical regions and are called by various names in different parts of the world. (willi-waws, typhoon, baguios)

    1. They develop over warm tropical seas close to the equator.

    2. They resemble cyclones, but are only a few hundred miles in diameter.

    3. They move away from the equator generally along the eastern edge of a continent.

  B. Typical winds of a hurricane are counterclockwise--Northern Hemisphere.

    1. Series of cloud bands spiral toward the center called the eye.

    2. The eye is a calm area having very low pressure.

    3. Winds outside the eye are violent (75+ miles/hour).

  C. Heavy rains accompany the hurricane.

    1. May cause flooding.

    2. Record rainfall during a 24-hour period: 46 inches during a Philipine hurricane in 1911.

  D. Hurricanes are named after girls (because they are unpredictable?).

  E. Watch is kept on hurricanes by the weather bureau, and hurricane warnings are issued because of the destructive nature of the storms.

IV. Tornadoes are the smallest, most violent, and short-lived of all storms.

  A. Tornadoes are most likely to occur on a hot, humid day in late spring or early summer when the sky is filled with thunderclouds.

    1. Cloud base develops extension.

    2. How tornadoes develop such force is not known. (They may develop as charged bodies.)

  B. Tornado Characteristics

    1. Move 25-40 miles in a path generally less than 300 yards wide.

    2. Winds up to 500 mph cause great destruction.

    3. Low pressures accompany tornadoes - buildings sometimes explode.

C. Called water spouts over water.

D. Midwestern states have most tornadoes.

  1. Iowa
  2. Kansas
  3. Arkansas
  4. Oklahoma
  5. Mississippi
  6. Illinois
  7. Indiana
  8. Missouri

E. Progress toward the prediction of the likelihood of a tornado has been made in recent years.

LESSON 12, Introduction

THE OCEANS AND THEIR CURRENTS

Objectives:

1. To accomplish a general overview of the oceans.
2. To develop an understanding of the causes of currents.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 17.
2. FOCUS ON EARTH SCIENCE, Chapters 11 and 12.
3. INVESTIGATING THE EARTH, Chapter 10.

Special References:

Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 9.

Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapters 32, 33, 34, 35, and 38.

Cowen, Robert C., FRONTIERS OF THE SEA, (Doubleday and Company, Inc.), 1969, Chapters 1, 6, 7.

Activities:

1. Investigating Currents
   ESCP 10-6 Text 241
   Teacher Manual 287-290

2. What makes sea water heavy?

To measure the amount of dissolved minerals in a typical sample of sea water, simply remove all the liquid and measure the remaining mineral matter. To do this, place a known amount of salt water (about 15 grams) in an evaporating dish. Determine the mass of the evaporating dish before adding the salt water. Then evaporate the water by heating slowly with a Bunsen burner. Use a low flame and avoid boiling because the mineral matter will tend to "pop out" of the evaporating dish as it dries. When all of the liquid is evaporated, weigh the evaporating dish. What is the mass of the minerals which stick to the bottom and sides of the dish? (Can you get this without scraping the minerals out of the dish?)

Now figure the percent of mineral matter contained in the water by dividing the mass of mineral matter by the original mass of sea water used.

FOLLOW UP DISCUSSION:

Discuss how the minerals got into the oceans and why these same minerals do not seem to be in the water of most lakes, rivers, streams, and ponds. Mineral concentration is a slow process of concentration through evaporation. While most of the water on land is not stationary (it tends to continually move toward the seas) the water in the oceans has no place to go. Nevertheless, the water level in the ocean does not continually rise, even though rivers are constantly adding water to it. Some water must be leaving the ocean. How? It evaporates into the atomosphere. Then, through condensation and precipitation, it returns to the continents as rain, dew, snow, etc.

Although the waters flowing into the seas are not very concentrated in minerals, they do carry very small amounts which have been dissolved out of the rocks on land. As the evaporation of water in the oceans continues, this minor amount of dissolved minerals concentrates, ever so slowly. Over a period of millions of years the ocean waters have concentrated to their present amounts.

3. Measuring density differences of water.

MATERIALS:

Paper or plastic straws, stopper, glass tube
Modeling clay, salts
Large beakers, cylinders or test tubes, burner
Sea water samples (may be simulated as before)
Cooking oil, antifreeze, alcohol, carbon tetrachloride, dye (Can be
done on flat-topped desks)

PRELIMINARY DISCUSSION:

The minerals which you found in the salt water in the previous experiment make it unfit to drink. Do they cause any other significant differences? Well, for one thing, certain objects float in water. Is there any difference between the "floating properties" of sea water and fresh water?

Every object which floats has some part which is submerged below the surface of the liquid. The size of this submerged part depends upon the weight of a given volume of the liquid and the mass of the floating object. If the liquid is very "heavy" the part which is submerged is very small and the object "rides high" in the liquid. On the other hand, if the liquid is very "light" the same object "rides low".

The mass of one unit volume of a material is called the density of the material. Therefore, we can actually compare densities by comparing the height above the liquid of a floating object. Remember, the greater the density of the liquid, the higher the object will float.

OBJECTIVES:

At the conclusion of this activity most students should be able to describe verbally or by diagram the construction of a hydrometer. They should be able to tell the relationship between "floating height" and density.

PROCEDURE:

This type of density is measured with a hydrometer. We will use a homemade hydrometer which is simply a piece of paper soda straw cut to the length of 8.5 cm with a small amount (a marble-sized bit) of clay at one end. The straw should be marked with 0.1 cm markings. Place the straw (clay end down) into a beaker of salt water and note where the water line is on the straw. Now place the straw in fresh water and again note the water line. How do the heights compare? Which has a greater density, fresh water or salt water?
(If you have trouble reaching conclusive results, make some quick checks. For example, "skinny" straws should work better than wide straws. Try imbedding a BB in the bit of clay. Fresh water may contain enough dissolved chemicals to make its density fairly close to salt water. If you suspect this, try a sample of distilled water. If everything you try fails, then just weigh equal volumes (at least 100 ml) of salt water, fresh water, hot water and cold water.

Explain why the minerals in the sea water change its density. Can you think of a simple activity to check your explanation? We have assumed that it is the added weight of the dissolved minerals which cause the difference in density. To make sure, we could add salt directly to the tap water sample. Does the density increase?

Are there any other ways to change densities besides changing mineral concentration? If you were lucky enough to make very sensitive hydrometers, you can see if temperature has any effect on density. (Try this before class. If you cannot get conclusive results, omit this part.) Use your hydrometer to compare the density of cold salt water (chilled in a refrigerator) and some hot salt water (which you can heat with a Bunsen burner). Which has the greater density, cold salt water or hot salt water? Can you explain why?

Note: If you have a flask full of tap water and close it with a one-hole stopper bearing a glass tube and then apply heat, what happens? How could this affect density?

What does this activity have to do with the fact that hot air rises and cold air sinks?

Why is the water in the oceans warmer at the surface and colder at great depths? (There are at least two answers to this question.)

Now, use the hydrometers to determine how "high" or "low" the hydrometer floats. Collect the following data.

	Water	Alcohol	Antifreeze	Cooking Oil	Carbon Tetrachloride	Dyed salt water
Height of hydrometer						
Mass of 100 ml of liquid						

Note: If a commercial hydrometer is available, you can have students make direct density readings and then compare them to calculated densities. The densities may be determined by dividing the mass (m) by the volume (v) of each liquid.

FOLLOW-UP DISCUSSION:

According to this activity, the floating height depends upon the mass of a unit volume of the liquid (density) and the mass of the floating object. The pressure depends upon the mass of a unit volume of the liquid. High ability students may begin to suspect that there is a connection between floating height and liquid pressure. There is. .

The straw sinks until the mass of the straw is equal to the mass of the liquid which the straw displaces. At this time the upward pressure on the bottom of the straw exactly balances its downward weight. If the liquid is "heavy" the straw does not have to displace as much to equal its weight, so it does not sink as far; therefore, it floats higher in liquids of greater density. We have come full circle from density to pressure, to floatation height, to density again.

4. Density Currents

MATERIALS:

Plastic shoeboxes and prop for one end
Food coloring
Sea water (may be simulated)
Muddy water (use fine-grained sediment)
Large beakers

PRELIMINARY DISCUSSION:

Dense water in parts of the oceans may result from:

a. Rapid evaporation in zones of warm dry climate, causing increased salinity.
b. Excessive cooling as in the polar regions.

c. Mixing of mud and silt with the water (called turbidity currents) which is characteristic of subaqueous landslides. These may be triggered by earthquakes, strong storms (hurricanes commonly are effective), or large influxes from the continent (e.g., the delta of the Mississippi River into the Gulf of Mexico).

What happens when liquids of different density come together?

OBJECTIVES:

At the conclusion, students should be able to name three types of density currents and their cause. They should be able also to explain verbally or by diagram the relative positions of the "light" and "heavy" liquids within the current.

PROCEDURE:

a. Effect of Increased Salinity

Place the plastic container on table with an object (e.g., eraser) under one end so that container is raised about one inch. Fill container with tap water. Add a few drops of dye to about 50 ml of salt water. Pour this salt water as a small "stream" into the raised end of the container. Be careful to pour slowly down the inside end of container. View the path of the dyed sea water as it flows along the container. Be sure to view from the side, not from above. Does the sea water flow above, below, or just mix with the tap water? Can you explain why?

b. Effect of Temperature Contrast

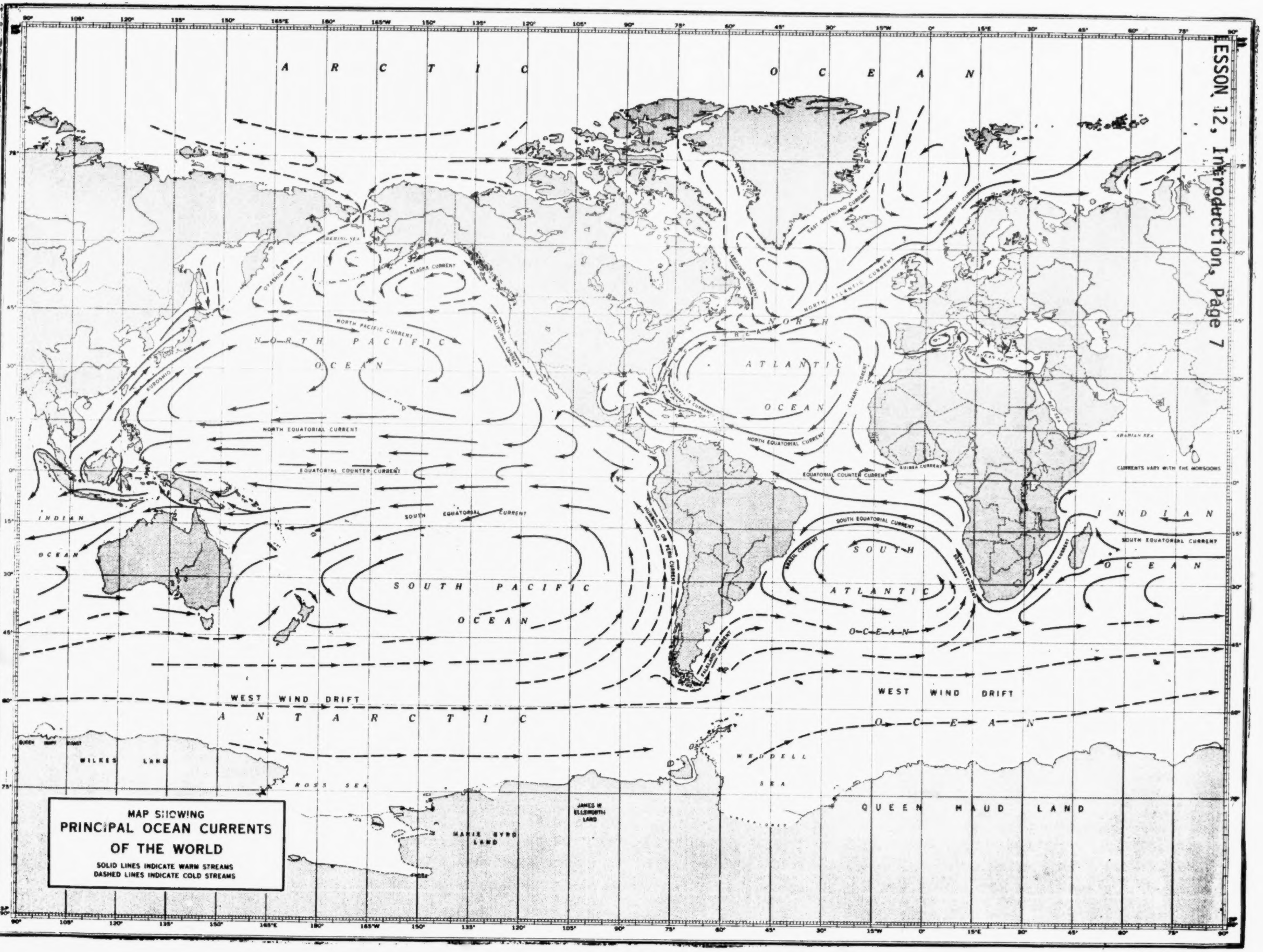
Put plastic container in same position as above. However, fill the container with hot salt water this time. (Salt water can be heated in a large beaker before pouring into container.) Be sure not to heat container itself over a flame as the plastic will melt. Now add a few drops of food coloring to about 50 ml of refrigerated salt water. Add this to the hot salt water, being sure to pour carefully using the technique described above. Again view the path of the dyed cold salt water as it flows along the container. View from the side as before. Does the cold salt water flow above, below, or just mix with the warm salt water? Can you explain why?

c. Turbidity Current (muddy water)

Have plastic container in the same position as above. This time fill the container with salt water at room temperature. Add 25 grams of sediment to about 100 ml of salt water and shake (or stir vigorously). Add this mixture to the container as previously. Again view the path of the muddy salt water as it flows along the container. As before, view from the side. How does the muddy water flow? Can you explain why?

FOLLOW-UP DISCUSSION:

Note that each of the three previous activities demonstrates how the denser water flows beneath the "lighter" water. You may want to reverse one activity and observe how the lighter water flows along the top. (It would be easiest to reverse either a or b for best viewing.)


ARCTIC OCEAN
BERING SEA
OYASHIO
ALASKA CURRENT
KUROSHIO
NORTH PACIFIC CURRENT
CALIFORNIA CURRENT
NORTH PACIFIC OCEAN
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTER CURRENT
SOUTH EQUATORIAL CURRENT
SOUTH PACIFIC OCEAN
HUMBOLDT OR PERU CURRENT
EAST GREENLAND CURRENT
LABRADOR CURRENT
NORWEGIAN CURRENT
NORTH ATLANTIC CURRENT
GULF STREAM
NORTH ATLANTIC OCEAN
ANTILLES CURRENT
CANARY CURRENT
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTER CURRENT
GUINEA CURRENT
SOUTH EQUATORIAL CURRENT
BRAZIL CURRENT
BENGUELA CURRENT
SOUTH ATLANTIC OCEAN
FALKLAND CURRENT
MEDITERRANEAN SEA
RED SEA
ARABIAN SEA
CURRENTS VARY WITH THE MONSOONS
INDIAN OCEAN
SOUTH EQUATORIAL CURRENT
AGULHAS CURRENT
WEST WIND DRIFT
ANTARCTIC OCEAN
QUEEN MARY COAST
WILKES LAND
ROSS SEA
MARIE BYRD LAND
JAMES W. ELLSWORTH LAND
WEDDELL SEA
QUEEN MAUD LAND
90° 105° 120° 135° 150° 165°E 180° 165°W 150° 135° 120° 105° 90° 75° 60° 45° 30° 15°W 0° 15°E 30° 45° 60° 75° 90°
75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90°

MAP SHOWING
PRINCIPAL OCEAN CURRENTS
OF THE WORLD
SOLID LINES INDICATE WARM STREAMS
DASHED LINES INDICATE COLD STREAMS

US COMM-CGS-DC 1958

LESSON 12

THE OCEANS AND THEIR CURRENTS

I. Introduction

A. Water is one of the few elements that exist on or near the earth's surface in all three physical states. (solid, liquid, and gas)

B. Over 98% of the water exists in the liquid state.

1. If we could spread the existing water over a smooth sphere the size of the earth in proportion to the space it occupies we would find the following depths:

a. atmospheric water - 0.03 meter

b. fresh water (lake and rivers) - 1 meter

c. ground water - 10 meters

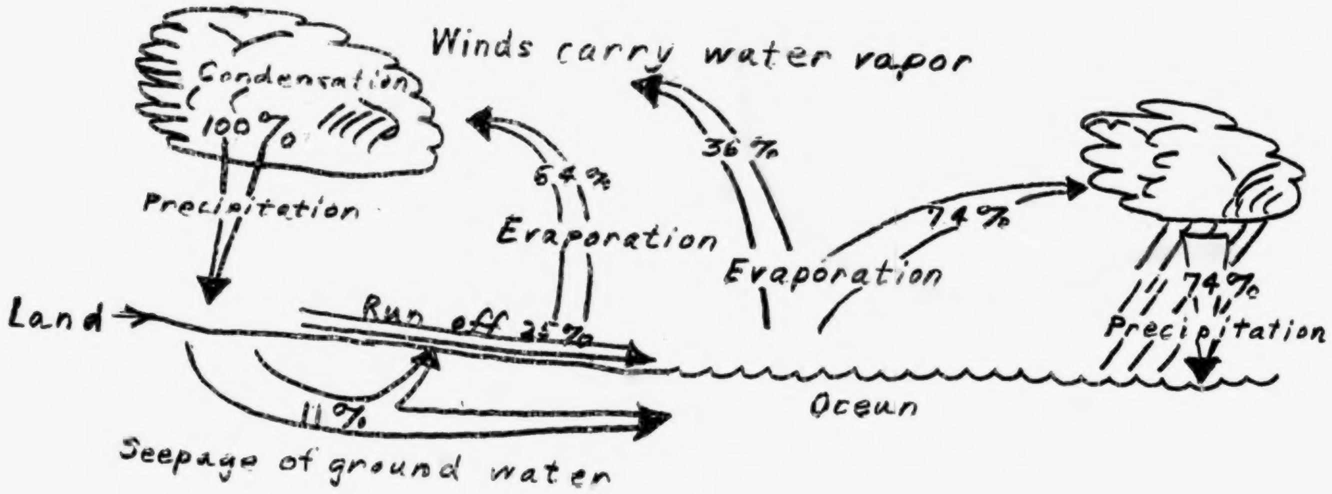
d. land ice - 45 meters

e. ocean water - 2685 meters

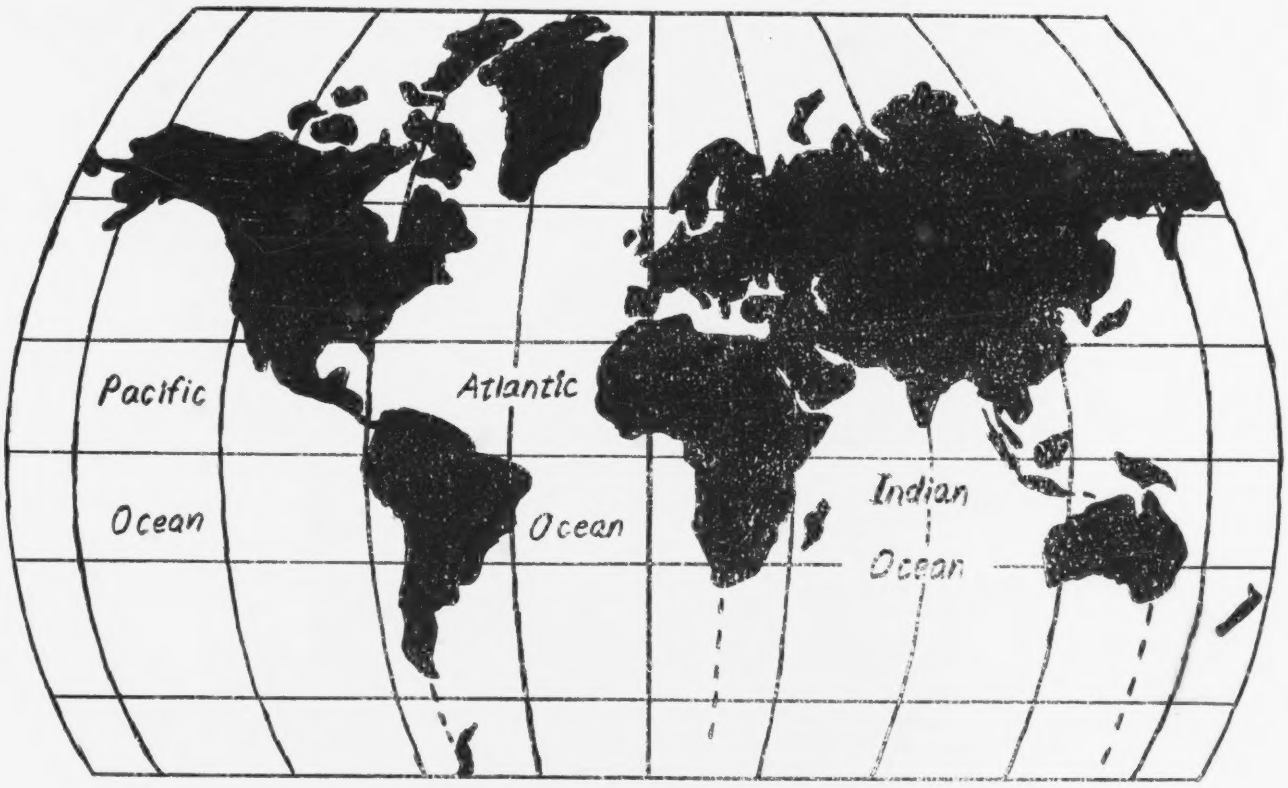
2. The water which fills the ocean basins occupies an area of $361 \times 10^6 Km^2$ or 70.8% of the earth's surface.

3. The ocean basins are, on the average, 3.8 Km deep and contain between 97% and 98% of all the water on earth.

C. The water on earth moves steadily through a cycle of evaporation, precipitation, and runoff known as the water cycle.


Condensation
100%
Winds carry water vapor
64%
36%
Precipitation
Evaporation
74%
Evaporation
74%
Precipitation
Land
Run off 25%
Ocean
11%
Seepage of ground water

D. The oceans of the world are one continuous body of water; however, they are separated geographically into three "oceans."



1. Atlantic Ocean $106 \times 10^6 Km^2 = 41 \times 10^6 mi^2$
2. Pacific Ocean $180 \times 10^6 Km^2 = 69.5 \times 10^6 mi^2$
3. Indian Ocean $75 \times 10^6 Km^2 = 29 \times 10^6 mi^2$

II. Water of the Sea

A. The waters of the oceans vary widely in their composition.

1. The composition is controlled mainly by three factors:
    - a. temperature
    - b. salinity
    - c. pressure
2. An "average" kilogram of ocean water contains:

a. sodium chloride	$NaCl$	23 gm
b. magnesium chloride	$MgCl_2$	5 gm
c. sodium sulphate	Na_2SO_4	4 gm

d. calcium chloride	$CaCl_2$	1 gm
e. potassium chloride	KCl	0.7 gm
		34.5 gm

plus traces of most of the other known naturally occurring elements. Thus, ocean water is actually a valuable mineral resource.

III. Ocean Currents are caused by winds and differences in density of ocean water.

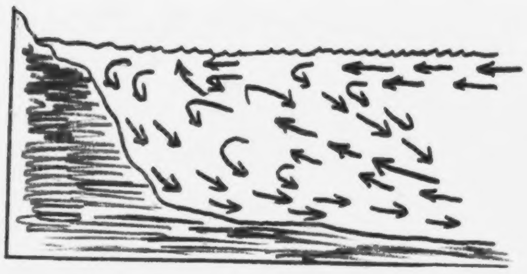
A. Winds cause surface currents.

1. Energy is transferred from the prevailing surface winds by friction between the air and water surface, creating the current.

2. Because of coriolis force the water is turned to the right in the Northern Hemisphere and the resulting current differs from the wind direction by about 45°. (See map showing Principal Ocean Currents of the World.)

3. Currents occasionally pile up against continental land masses. Then gravity tends to equalize the water level and sets up other currents.

a. These counter currents often result in upwellings of colder waters, bringing in mineral material. The upwellings are often the site of profuse marine life.

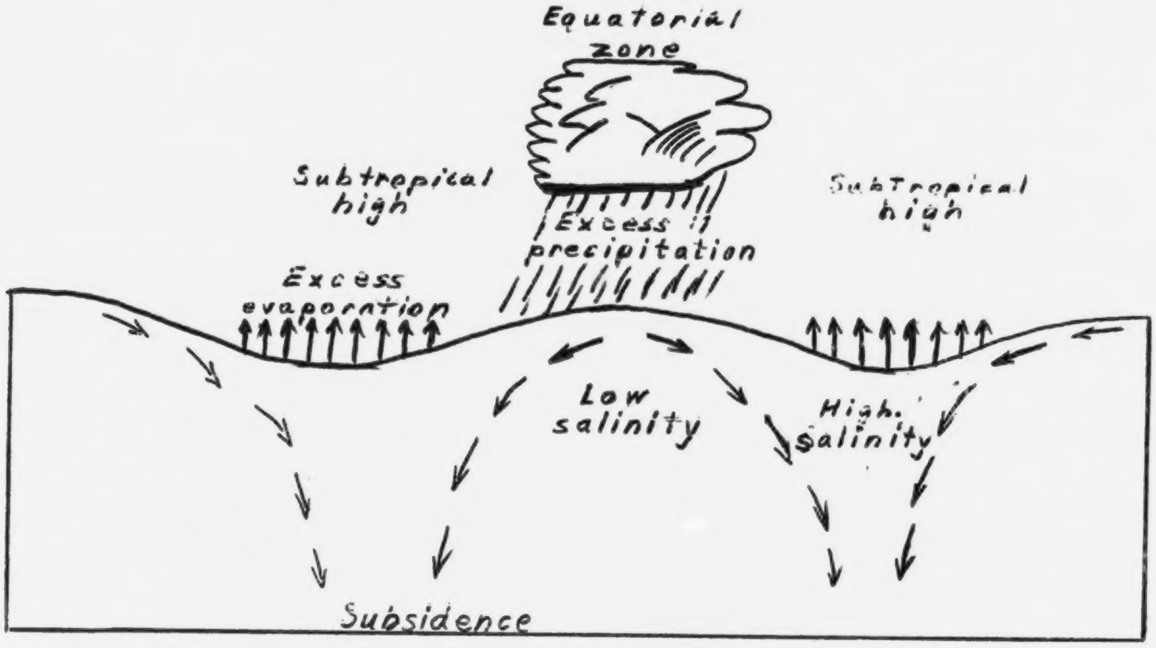


B. Heating, cooling, dilution, and concentration which change the density of sea water also cause currents.

1. Denser waters move downward and less dense waters move upward.

a. Thus, colder waters tend to sink and warmer waters rise. (Impact of currents and friction between currents or between the current and the bottom may alter this general statement.)

b. Changes in salinity also change densities causing currents.


Equatorial zone
Subtropical high
Subtropical high
Excess precipitation
Excess evaporation
Low salinity
High salinity
Subsidence

LESSON 13, Introduction

BOTTOMS, WAVES AND TIDES

Objectives:

1. To develop a concept of the ocean basins.
2. To understand tidal phenomena.
3. To understand the causes, structure, and behavior of waves.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 17.
2. FOCUS ON EARTH SCIENCE, Chapters 11 and 12.
3. INVESTIGATING THE EARTH, Chapter 10.

Special References:
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 6, 9, 27.
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapters 17, 36, 37.
Bascom, Willard, WAVES AND BEACHES (Doubleday), (Science Study Series S-34), Chapters 2, 3, 4, 5, 6, 7, and 8.
Revelle, Roger R., FRONTIERS OF THE SEA (Doubleday), Chapters 3 and 5.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 23 and 24.
Gilluly, et al. PRINCIPLES OF GEOLOGY (W. H. Freeman & Co.), Chapter 16.

Activities:

1. Mapping the ocean floor.

MATERIALS:

Slinky (toy)
Timing device

OBJECTIVES:

We can get a profile of the ocean floor by measuring the distance from the surface to the bottom as a ship moves along a predetermined course. A line, similar to that drawn across land contours as described earlier, can be traced.

The activity described here is designed to simulate an echo-sounding study made to determine the ocean floor irregularities. The principle of the echo sounder is simply this: Sound waves produced on ship will travel to the floor of the ocean and bounce back to the ship.

PROCEDURE:

Slinky Demonstration Make a compressional (push-pull) wave with a slinky. Notice how the wave travels the length of the slinky and then returns to the point of origin. The same is true of a compressional wave produced from a ship. If we know the speed at which the wave travels down the spring we can find the length of that spring.

Similar studies under controlled conditions have been run for sound waves generated from ship to the ocean floor (known depth). The rate at which these waves travel is measured in this way. Once the techniques of sound wave generation are perfected and appropriate recording devices installed, the ship is ready to run a course and compute a profile of ocean floor topography.

We know that sound waves travel in water at a speed of 4,800 feet per second. The distance to the ocean floor can be computed by using the formula:

$$\frac{\text{time x speed}}{2} = \text{depth}$$

The following provides you with raw data on a series of soundings. Compute the distance for each of the soundings, then plot the points on the attached graph. Connect each of these points to form a profile of the ocean floor topography along the traverse line of the ship.

RAW DATA on SHIP SOUNDINGS

Distance from beach in miles	Time for Signal Return in seconds	Depth in feet
10	.1	
20	.2	
30	5.2	
40	5.4	
50	5.6	
60	5.6	
70	5.6	
80	5.6	
90	8.4	
100	6.4	
110	5.6	
120	5.6	
130	5.6	
140	3.1	
150	3.1	
160	5.6	
170	4.6	
180	5.6	
190	2.9	
200	0.0	
210	0.0	
220	2.4	
230	3.1	
240	3.1	

2. Particle action in wave motion.

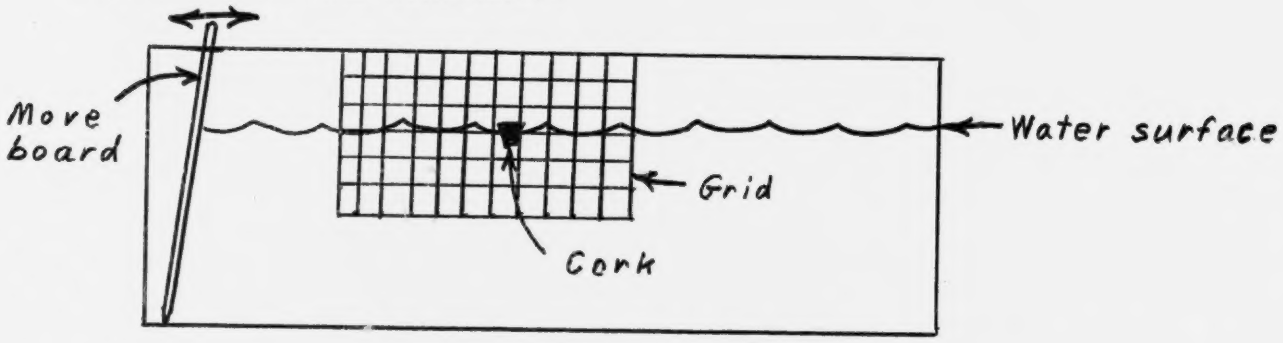
MATERIALS:

Aquarium or other transparent container
1 cm grid-transparency, float, flat board

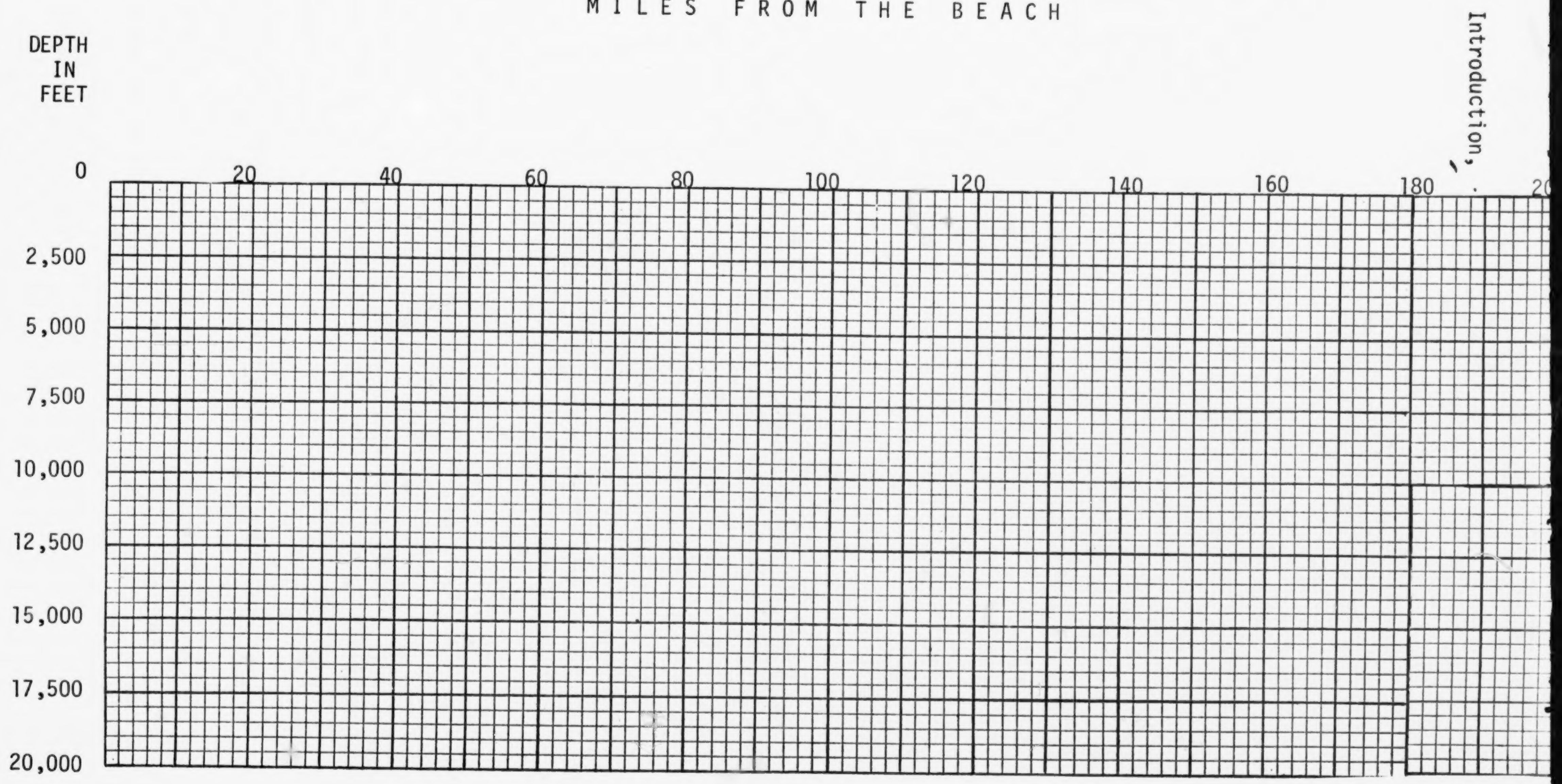
PROCEDURE:

1. Fill the container with water and tape the grid to the side of the container so that you can see the water surface as a line on the grid.

2. Have someone generate waves by moving the flat board (cork stopper will do) in the container.



3. Place the float in the water next to the grid and plot its motion. What path does it follow? Also observe the float from above and note its apparent motion.

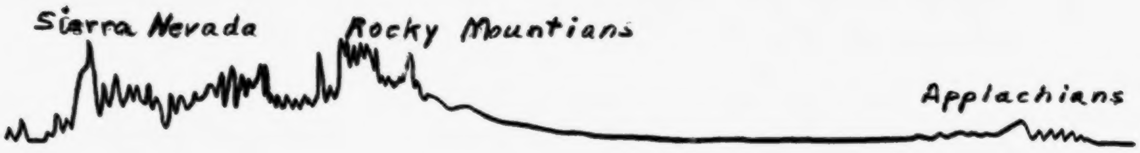

MILES FROM THE BEACH
DEPTH IN FEET
0
2,500
5,000
7,500
10,000
12,500
15,000
17,500
20,000
20
40
60
80
100
120
140
160
180

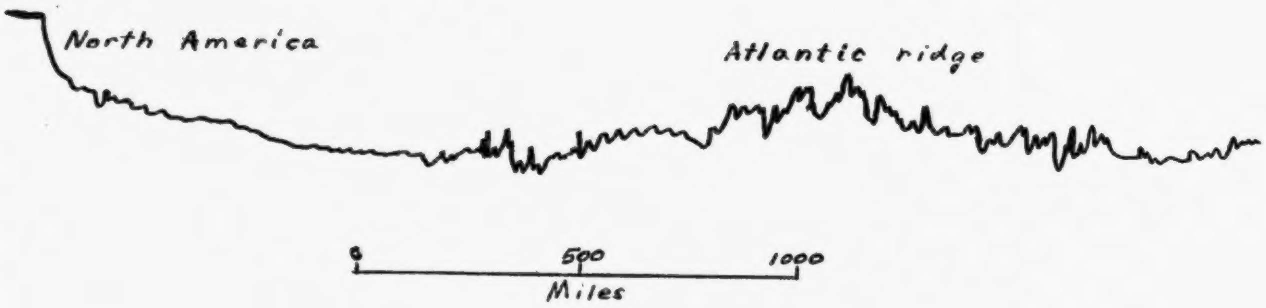
LESSON 13

BOTTOMS, WAVES, AND TIDES

I. The Ocean Bottom

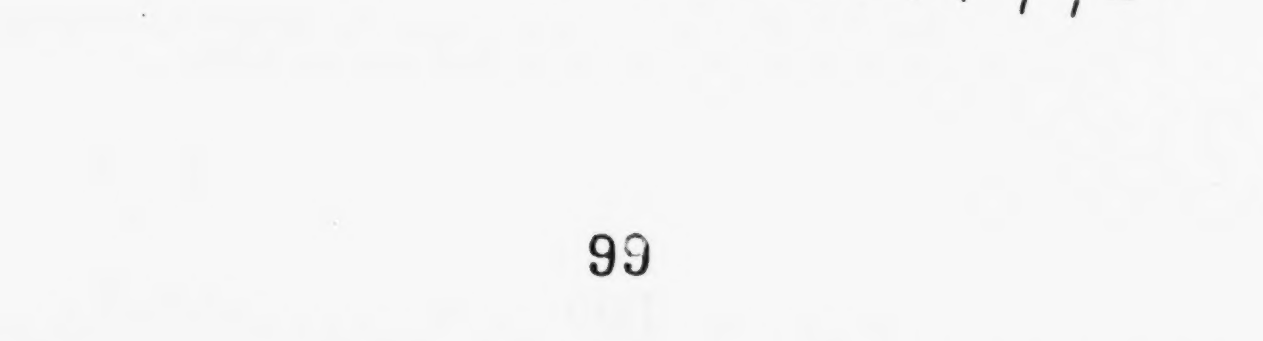
A. The ocean basins are not smooth but show considerable relief.


Sierra Nevada
Rocky Mountians
Applachians


North America
Atlantic ridge
0
500
1000
Miles

B. The North Atlantic Basin contains examples of most of the typical basin features.

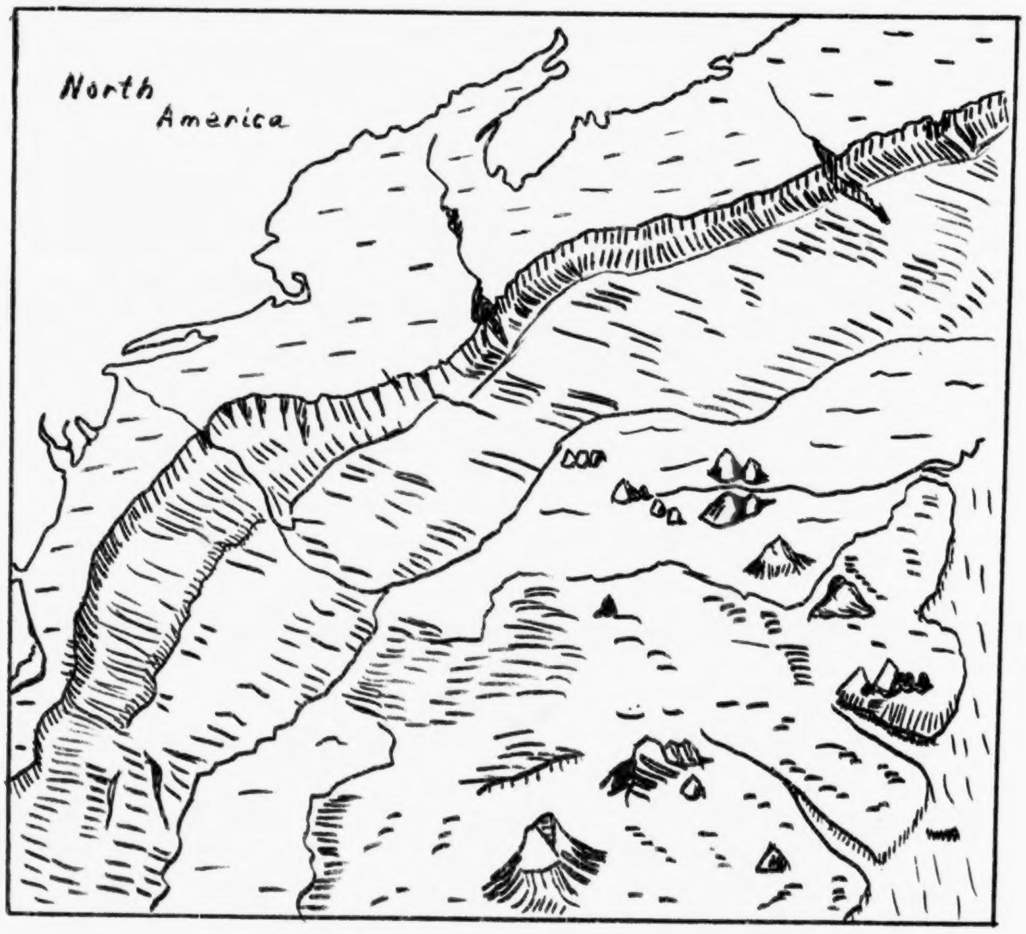
1. The Continental Shelf is a relatively smooth sloping plain 75 to 100 miles wide and sloping to a depth of about 600 feet at the outside edge. (The shelf off the North Carolina coast is particularly famous because of the shoaling characters of its waters, its violent currents and major storms which have made it the "Graveyard of the Atlantic.")


Continental shelf
Continental slope

2. The Continental Slope descends into the ocean basin floor (12,000 feet) and is cut by submarine canyons.

   a. The canyons appear to be due, in part, to flows of muddy water (turbidity currents).

   b. These flows are thought to account for the flat abyssal plains by the filling of the irregular basin floor.



3. Other features include:

   a. Seamounts - thought to be ancient volcanic mountains - usually occur in isolated peaks.

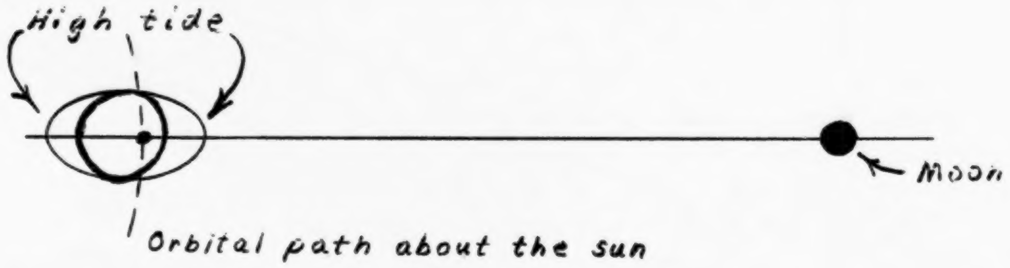
   b. The Mid-Atlantic Ridge - mountain range in the center of the Atlantic, equal to the Rockies in size but submerged except for the Azores. Related to major crustal rift zone and part of evidence of Continental Drift.

   c. Trenches (30,000 feet or more) usually border continents and are also associated with Continental Drift.

II. Tides are caused by the gravitational pull of the moon and the sun on the oceans of the earth.

A. There are usually two tides every day. That is; the tide changes about every six hours, rising and falling to yield two high tides which are about 12½ hours apart.

B. The presence of two high tides is due to the earth and moon's relationship.



1. The tide on the side of the earth nearest to the moon is due to gravitational pull.

2. The tide on the far side is due to the centrifugal force of the earth-moon revolution.

C. Two other factors affect the tides.

1. The relationship of the sun to the earth-moon system.

a. Spring tides (of unusually great range between low and high) usually occur when the sun and moon are in conjunction and opposition. (about 20% greater)

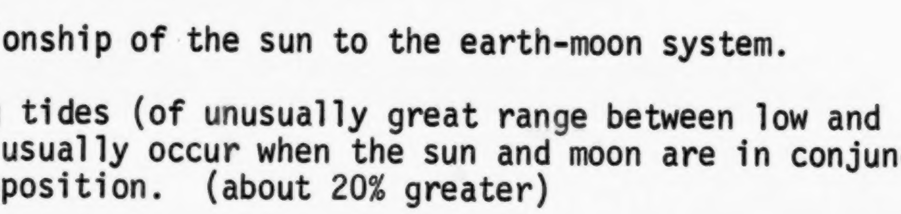
b. Neap tides (of small range between low and high) usually occur when the sun and the moon are in quadrature. (about 20% less)

2. The slope and size of the basin.

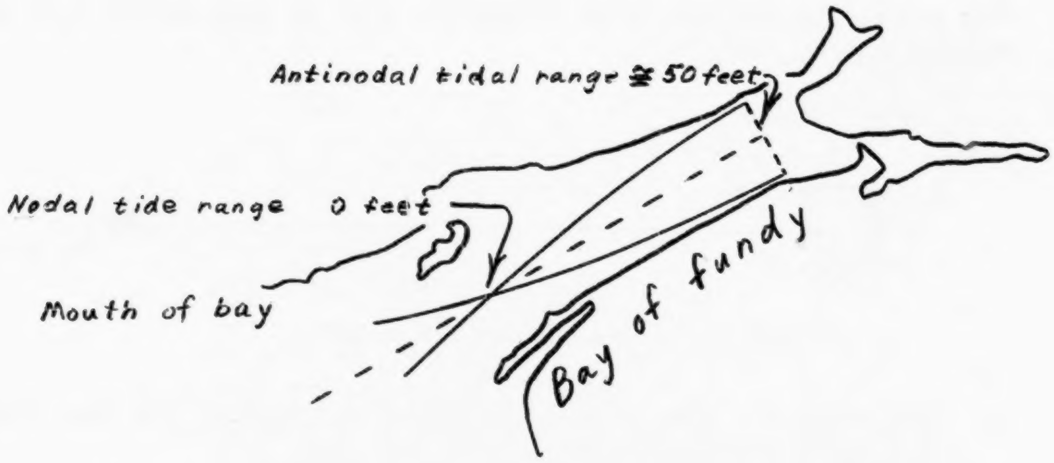
Some basins, estuaries, and rivers are located or shaped in such a way that strange tidal behavior occurs.

a. One way in which exceedingly high and low tides may occur is by the formation of standing waves.

(1) In a standing wave the water surface moves up and down in a rhythmic way, but the crests and troughs do not travel horizontally.



(2) In certain lakes, estuaries, and rivers, the slope and size of the body of water are related to the period of the waves in such a way that standing waves are generated.



The spring tides at the antinode in the Bay of Fundy have a range of over 50 feet while there is almost no tide at the mouth of the bay. (The natural period of the bay has been calculated at 12 hours which is close to the natural diurnal period of the tides.)

3. Tidal waves may be developed in such basins and sweep up river as tidal currents or bores. In other places, the tidal range may be extreme.

III. Waves

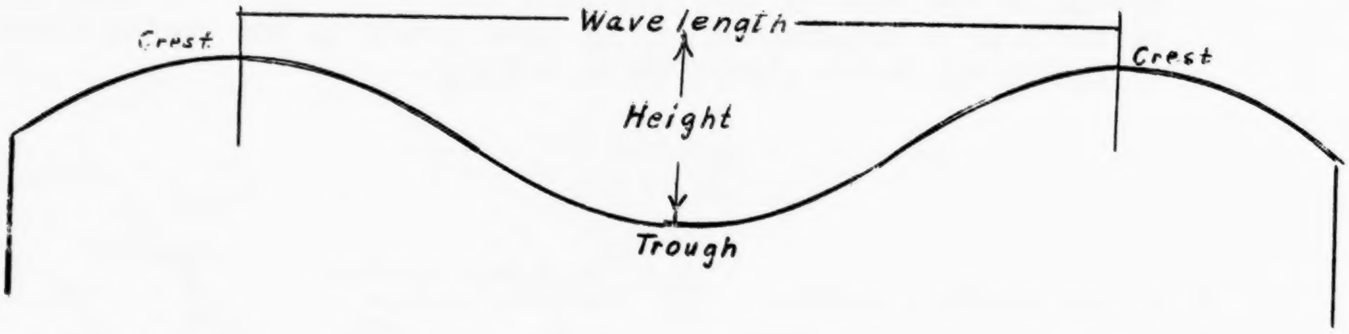
The waves which occur at the surface of the ocean are caused by wind blowing across its surface.

A. The characteristics of the waves depend upon:

1. The speed of the wind.
2. How long the wind blows.
3. The wind's fetch (how long the straight-line distance over the water is that is affected by the wind.)

B. As wind speed, duration, and fetch increase, so does wave size. However, size is limited by friction and gravity. A wind of 50 knots blowing over a distance of 1500 miles for three days is required to develop a wave of maximum size.

C. Wave Structure



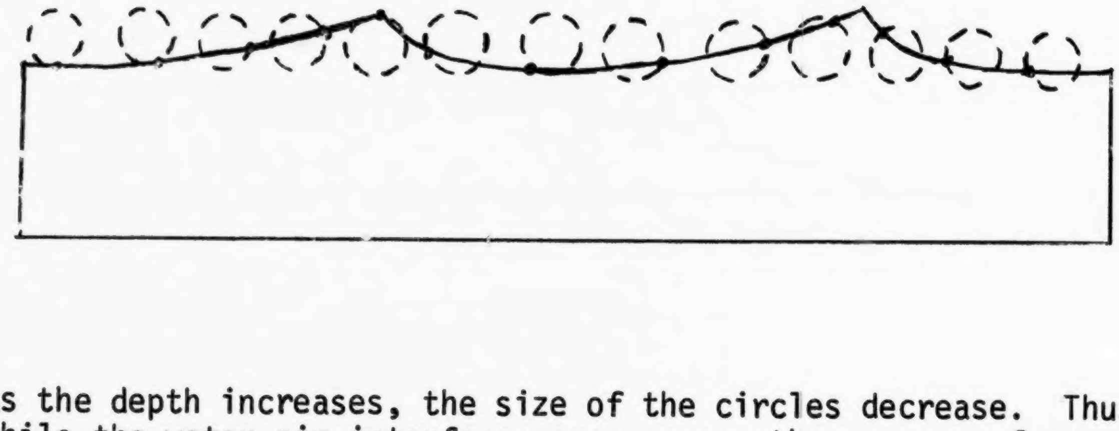
1. The period (T) of a wave is the time required for one complete wave to pass a given point.

2. A wave length is the distance from crest to crest.

3. The wave speed is the $\frac{\text{wave length}}{\text{period}}$.

D. Energy and motion in deep water waves.

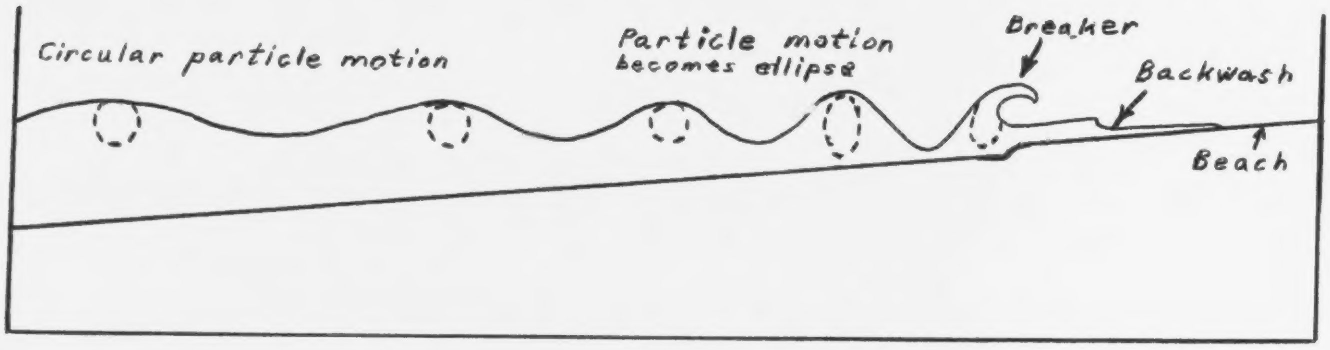
If a small float is placed in the water's surface and observed, it will be seen to move back and forth ⟷ and up and down ↕. On closer observation, the float can be seen to follow a path as shown below.



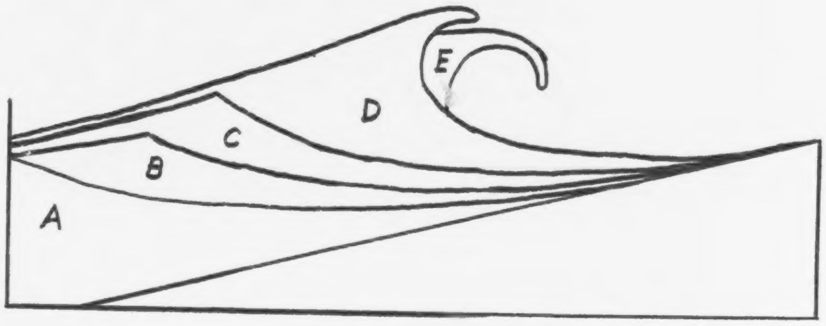
As the depth increases, the size of the circles decrease. Thus, while the water-air interface moves across the ocean surface, the particles themselves do not move but simply transfer the motion from one to another.

E. Shoaling water

As a wave approaches the shore, the water becomes less deep, and the energy of the wave is confined to a smaller space. The wave form responds by a lengthening of the wave crests as the particle motion is converted from a circle to an ellipse.


Circular particle motion
Particle motion becomes ellipse
Breaker
Backwash
Beach

As the water becomes more shallow, the wave height increases until the ratio of the wave height to wave length reaches 1:7 at which point gravity causes the wave to collapse. The collapse forward is known as breaking and generates a swash which moves up onto the beach. Gravity then reverses the flow creating a backwash which carries the water back from the beach to the ocean.



LESSON 14 , Introduction

SHORE PROCESSES

Objectives:

1. To understand the effect of waves on the shore.
2. To develop a mental image of types of shorelines, their features, and how they are created.

References:

1. THE EARTH - SPACE SCIENCES, Chapter 17.
2. FOCUS ON EARTH SCIENCE, Chapter 12.
3. INVESTIGATING THE EARTH, Chapters 10 and 13.

Special References:
Bascom. WAVES AND BEACHES (Doubleday), Chapters 1, 9, 10 and 11.
Revelle. FRONTIERS OF THE SEA (Doubleday), Chapters 4, 5 and 9.
Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press Company), Chapters 23 and 24.
Gilluly, *et al*. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company), Chapter 16.
Wolfe, *et al*. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 17.
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 7.

LESSON 14

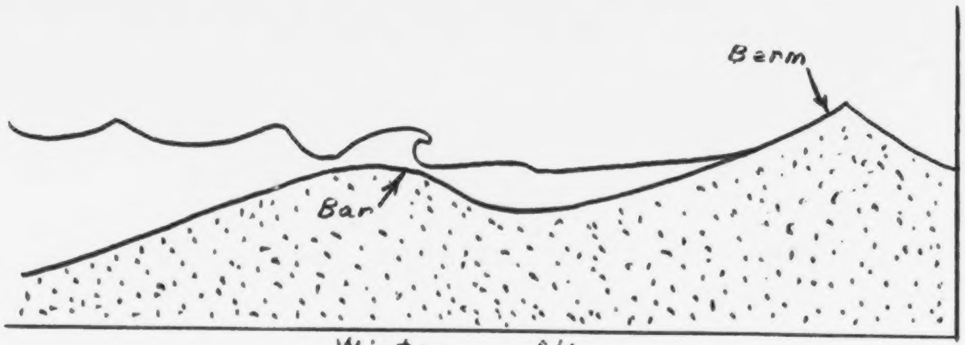
SHORE PROCESSES

I. Wave Erosion

During relatively calm periods, waves do little in the way of erosional work and tend to build up shorelines by moving sand onto the shore. However, during storms tremendous waves are generated throwing enormous amounts of water against the beach. During such storms, waves carry away considerable quantities of sand and reshape shorelines.

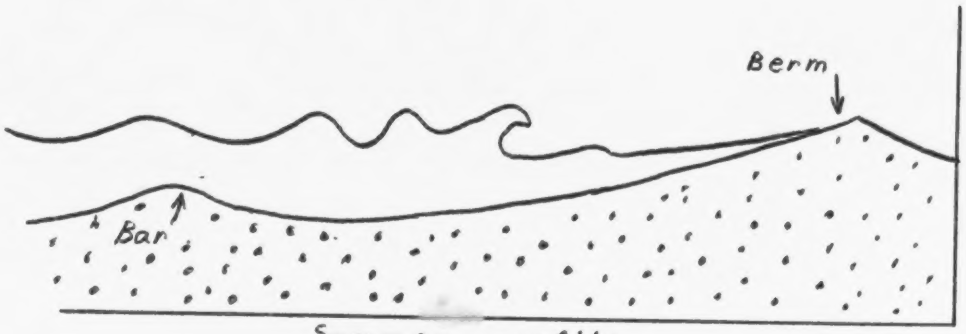
A. Wave Action

Water crashing on shore tends to build a deposit on shore called a berm. The retreating backwash carries some material back offshore and forms a deposit called an offshore bar.



Winter profile

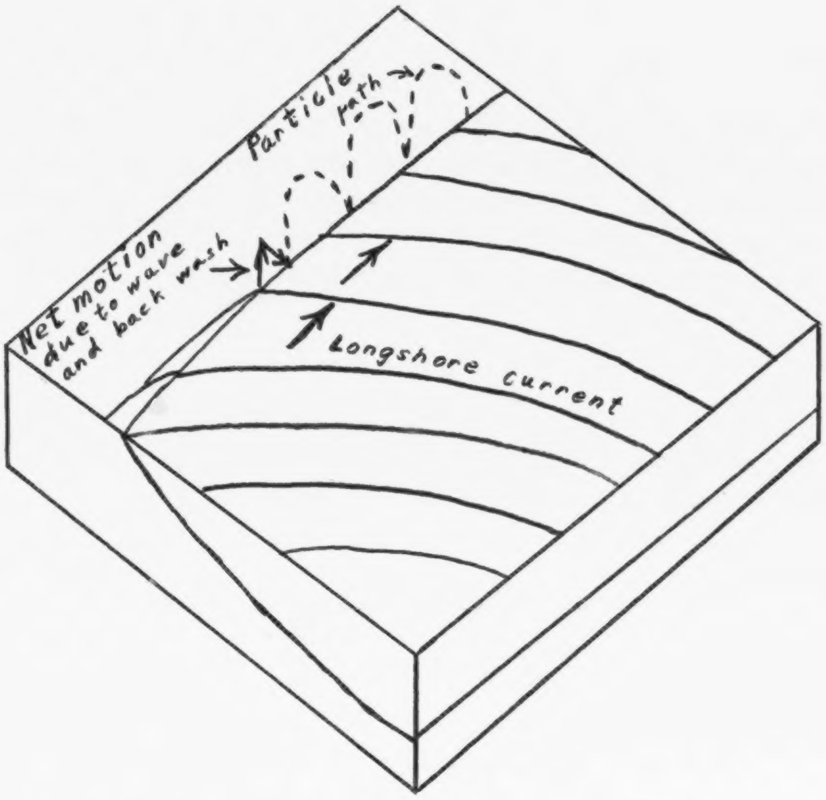
1. Because winter storm action is severe, the berm tends to be steep and the bar is well developed.
2. In summer, with gentler seas, the berm tends to smooth out and bars nearly disappear.



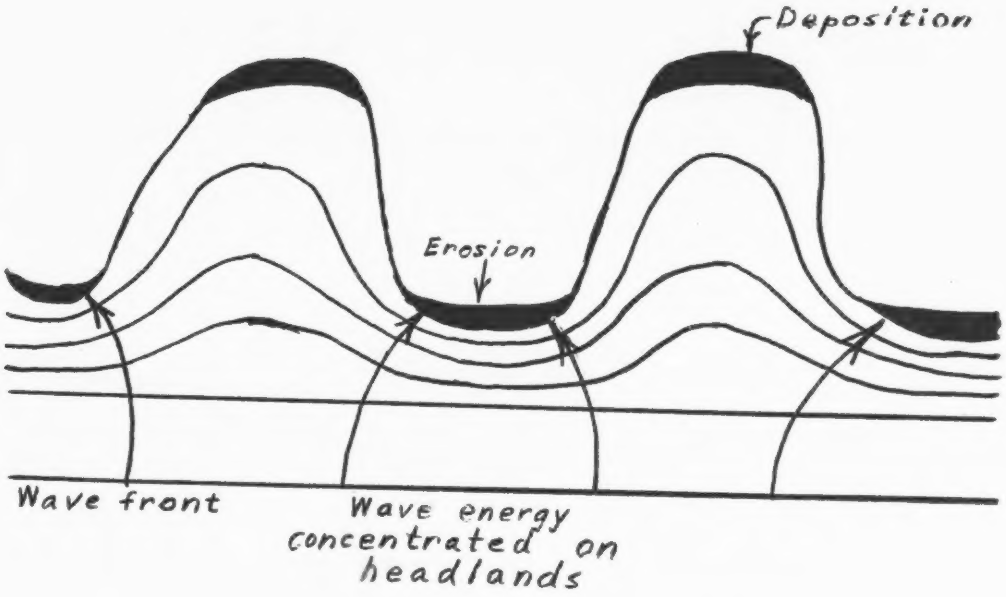
Summer profile

B. Waves often strike shorelines at acute angles. When waves strike a shoreline obliquely, two processes occur simultaneously.

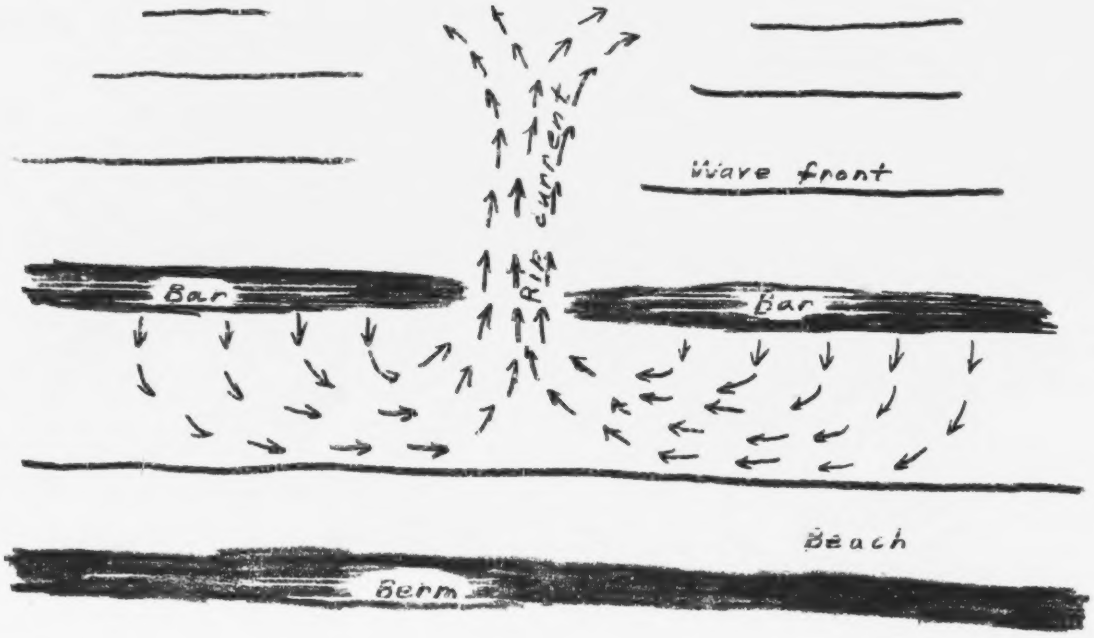
1. The waves create a long shore [redacted]allow water zone.
2. The rock and sand particles on the beach are moved down the beach in a series of arched paths.


Particle path
Net motion due to wave and back wash
Longshore current

C. When the shoreline is not straight, waves tend to be refracted, concentrating energy on the headlands.


Deposition
Erosion
Wave front
Wave energy concentrated on headlands

D. When bars are well developed, rip currents tend to occur. Rip currents are due primarily to piling of water into the trough between the bar and the beach. When this water finds an escape route through the bar, the flow may carry swimmers out to dangerous distances from the beach.



II. Shorelines

The shape of a shoreline is determined by many factors; however, the relative motion between land and sea level is the most important.

A. Shorelines can be classified as:

1. Emergent
2. Submergent
3. Neutral
4. Compound

B. A changing shoreline level can be caused either by a lowering or raising of sea level or a lowering or raising of the land. In some cases, both may occur simultaneously.

C. Each type of shoreline develops in a characteristic manner showing particular features.

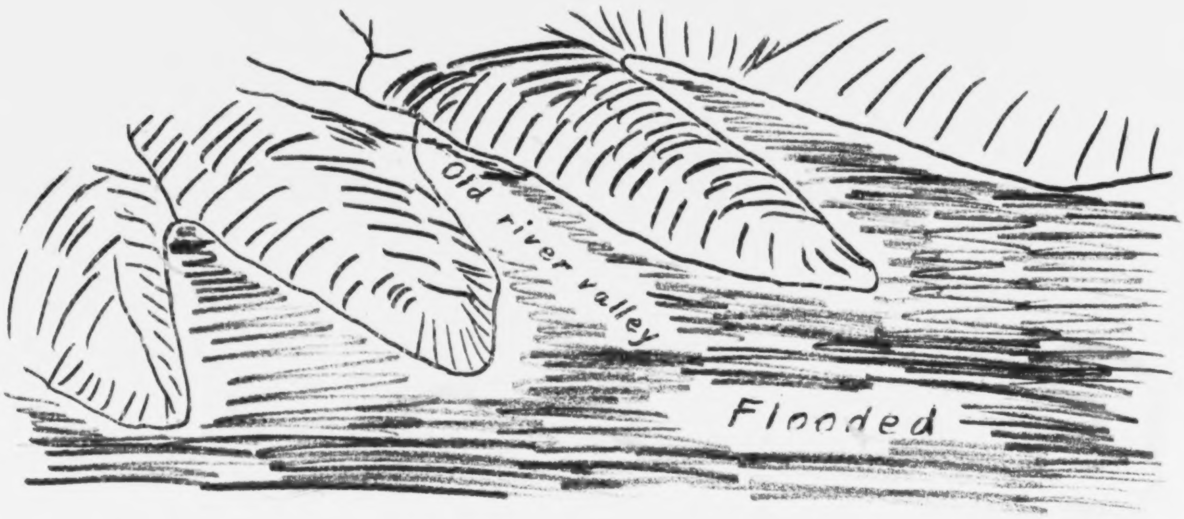
D. In certain areas, a periodic reversal of motion may result in a shoreline having the character of both submergent and emergent. These cases are referred to as compound shorelines.

III. Characteristics of the major shoreline types

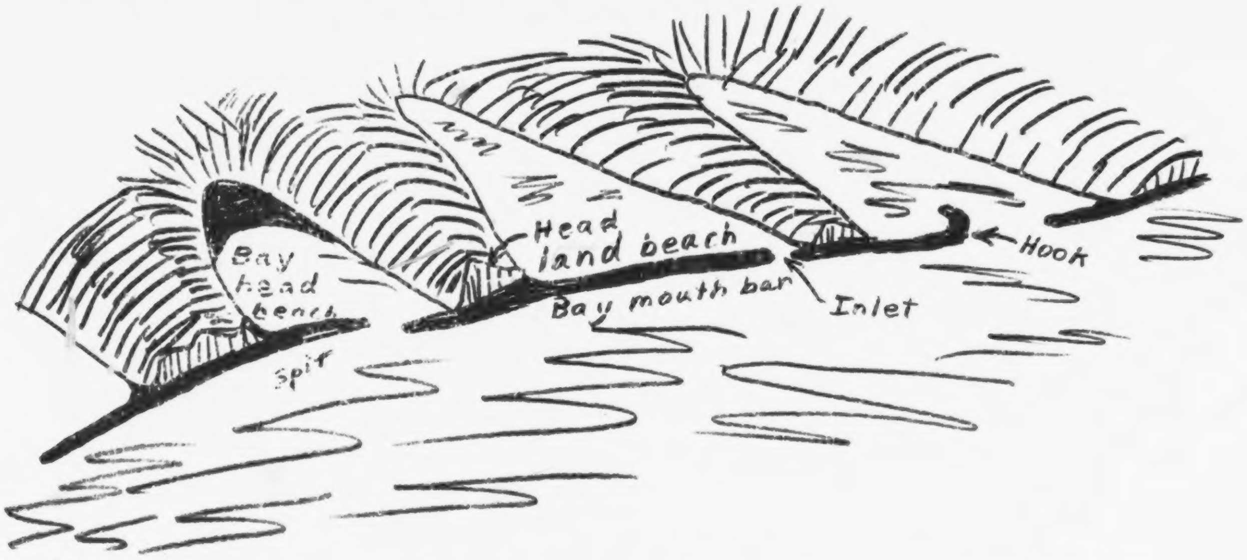
A. Submergent shorelines develop when the land surface moves down relative to sea level.

1. Submergence results in flooding of what was previously land area. Stream and river valleys may form extensive estuaries.

a. These are soon closed by numerous bars as waves develop headland beaches and move the sand in the still waters of the bays.

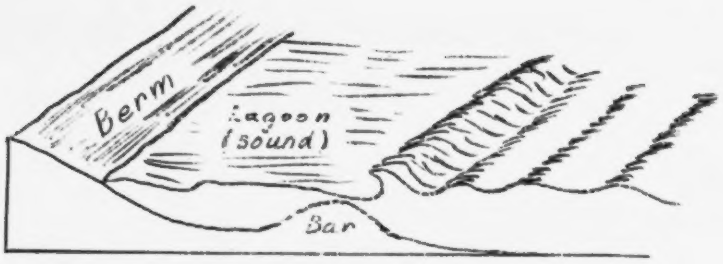

Old river valley
Flooded

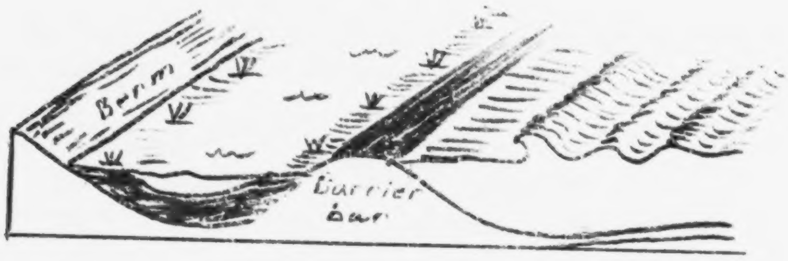
b. As time passes, the closed bays fill in, and the beaches are enlarged until the irregular shoreline is reshaped and straightened.

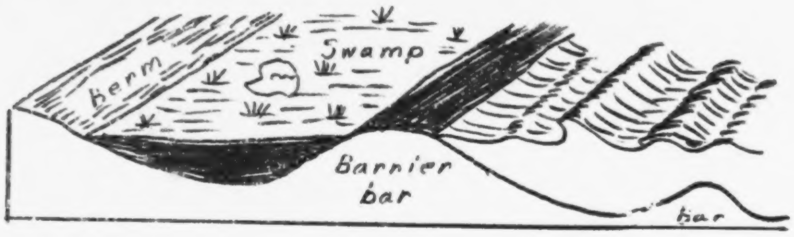

Bay head beach
Head land beach
Bay mouth bar
Inlet
Hook
Spit

2. When the sea floor sinks very slowly and uniformly, flooding a previously static sea floor (such as the Continental Shelf along the Carolina Coast), barriers or long shore bars tend to develop.

Series of these filled-in lagoons can be seen on Florida's Atlantic Coast. (See charts of the above on following page.)

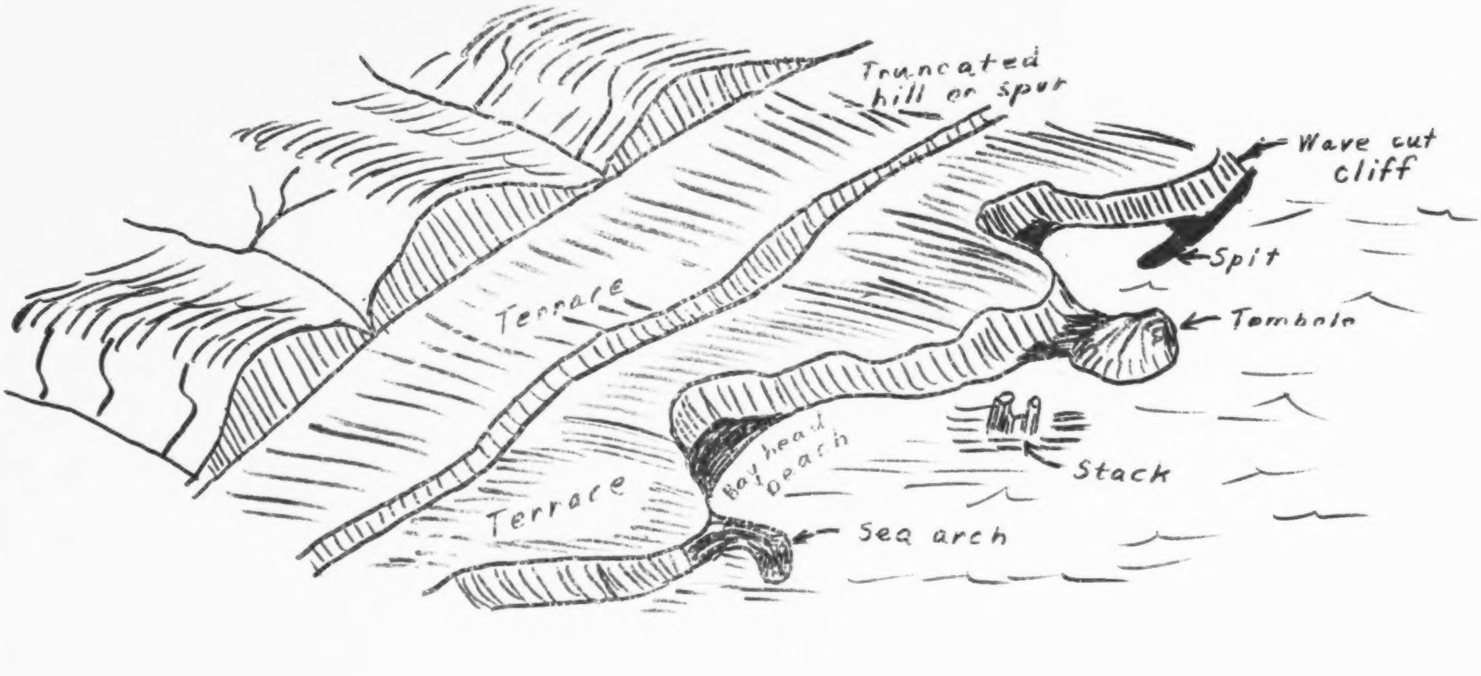

Berm
Lagoon (sound)
Bar


Berm
Barrier bar


Berm
Swamp
Barrier bar
bar

B. Emergent shorelines occur where the land is moving up relative to sea level.

1. The upward motion of a land surface normally tends to be jerky with sudden motion interspersed with thousands of years when no motion occurs. During the intervals between movements, the waves cut terraces and create other shoreline features.


Truncated hill or spur
Wave cut cliff
Spit
Terrace
Tombolo
Stack
Bay head beach
Terrace
Sea arch

a. Among the features developed, some of the more prominent are:

(1) Stacks
(2) Wave-cut cliffs
(3) Wave-cut terraces or benches
(4) Sea caves
(5) Sea arches

b. Wave refraction will also create bars, beaches, and tombolos by moving sand materials from place to place.

C. Neutral shorelines are formed by processes other than changes of sea level (lava flows, glacial shoreline, etc.). Neutral shorelines may be submerged or elevated after their formation.

D. Compound shorelines result from complex movements, resulting in forms common to more than one type of shoreline (a mixture of neutral and submergent features, or submergent and emergent features).

LESSON 15, Introduction

MINERALS

Objectives:

1. To introduce minerals as the basic building blocks of rocks.
2. To gain an understanding of properties of minerals and the process of identification.

References:

1. THE EARTH SPACE-SCIENCES, Chapter 22.
2. FOCUS ON EARTH SCIENCE, Chapters 3 and 4.
3. INVESTIGATING THE EARTH, Chapter 2.

Special References:

Wolfe, *et al*. EARTH AND SPACE SCIENCE (D. C. Heath, Atlanta), Chapters 3 and 4.

Holmes, PRINCIPLES OF PHYSICAL GEOLOGY, (Ronald Press, New York), Chapter 4.

Gilluly, *et al*. PRINCIPLES OF GEOLOGY (W. H. Freeman & Co.), Chapter 2.

Stuckey and Steel, Educational Series No. 3 GEOLOGY AND MINERAL RESOURCES OF NORTH CAROLINA (Division of Mineral Resources, Raleigh).

Activities:

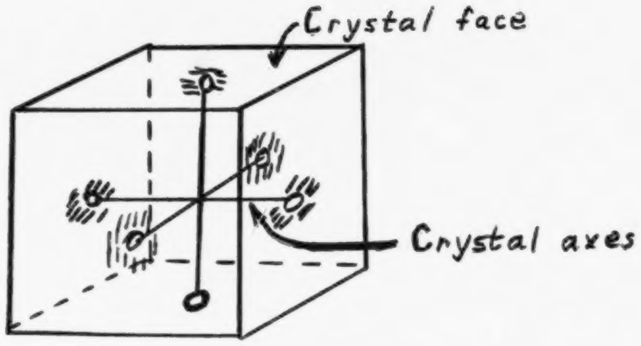
1. Investigating rocks and minerals
   ESCP 2-2 Text 39

2. Investigating the "Big O"
   ESCP 2-7 Text 50

3. Crystal Systems Exercise

   We have been studying the way in which a crystal grows. The purpose of this exercise is to become acquainted with the major patterns in which crystals grow. You will remember that crystals can be described by using the axes along which their faces grow. Therefore, if we know the length of the axes and the angles between them we can describe the crystal.

   Crystals grow in thousands of shapes and sizes but all crystals can be classified into six major catagories or classes. The first part of this laboratory exercise consists of constructing a model of each of the major crystal types. Attached to this paper you will find patterns for each of the major crystal types. Using scissors and paste construct each of the models provided. You may find it helpful to paste the patterns to stiff pieces of paper before cutting them out. When you have completed the models, take a needle and thread and put axes into each model. Remember a crystal axis is always at right angles to the surface of the crystal. The diagram on the following page shows the axes for a cubic crystal.

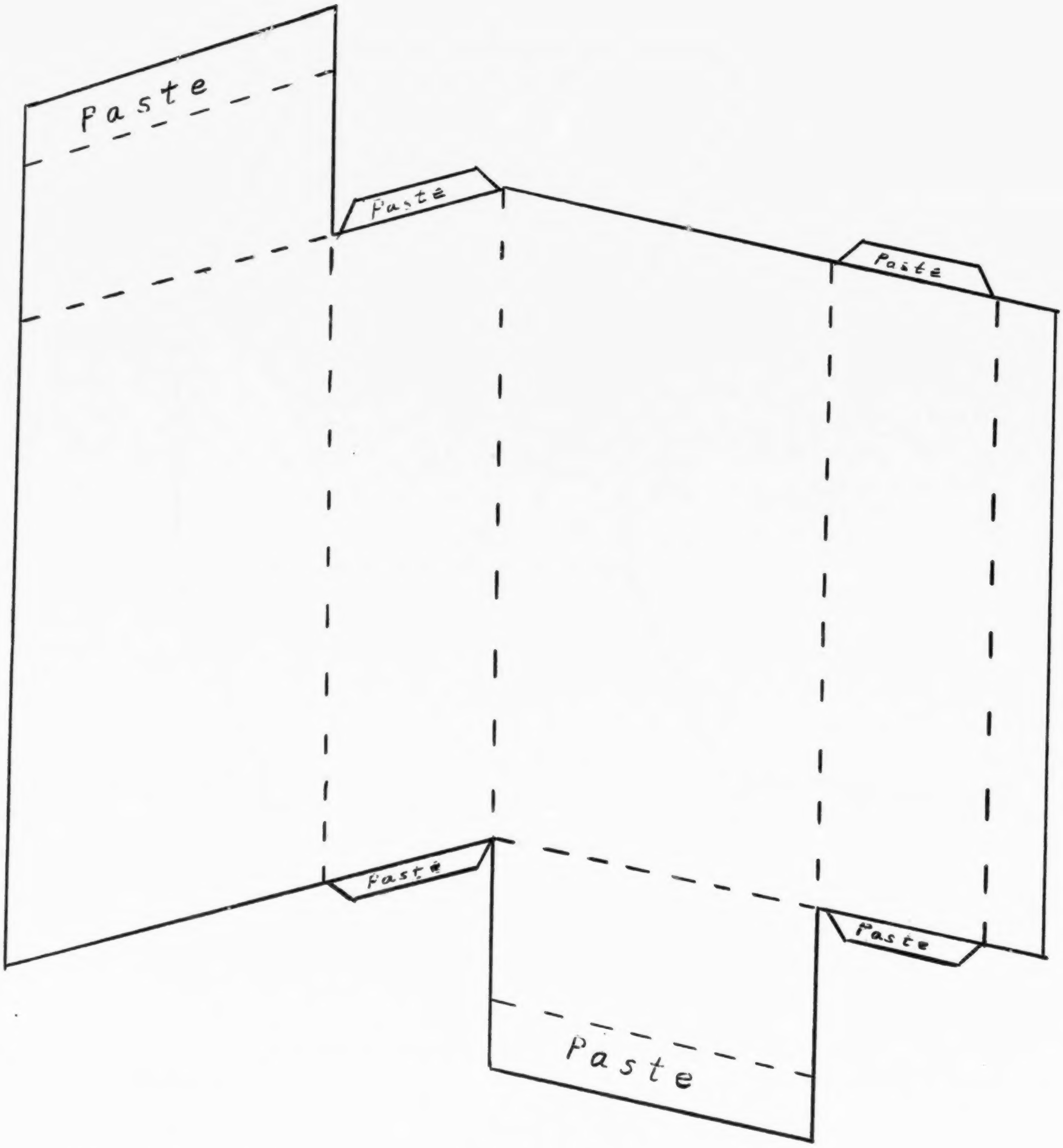


Crystal Systems Exercise

Instructions: Try to arrange the crystals you have constructed on your desk according to size and shape. The table below gives the crystal name. Using a textbook or any other reference you desire fill in the table. Under length of axes indicate whether the axes are longer, shorter, or the same length as one another. Under angles between axes indicate whether the axes are at right angles or other than right angles to one another.

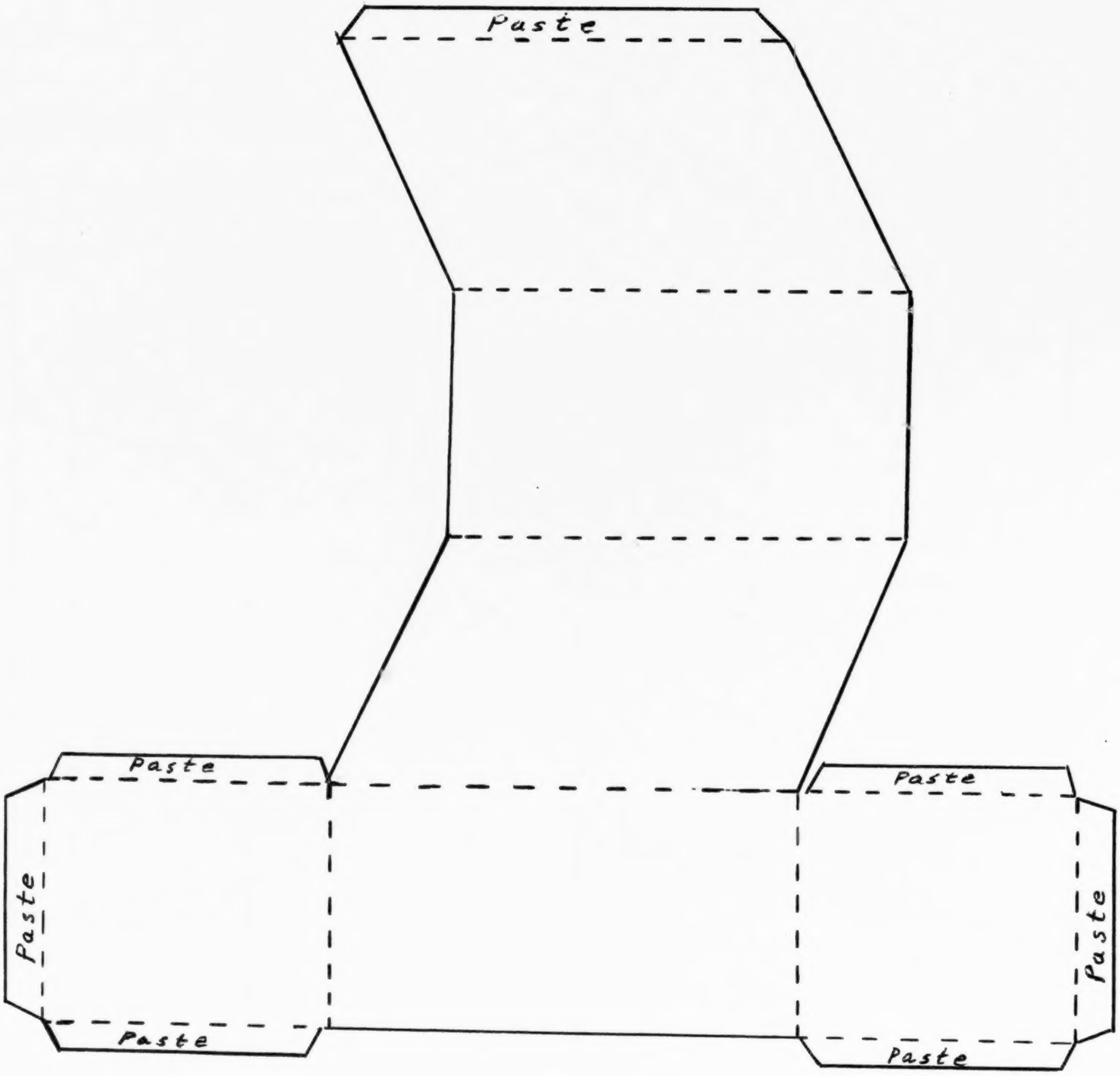
Crystal System Name	Length of axes	Angles between axes
Cubic		
Tetragonal		
Orthorombic		
Hexagonal		
Monoclinic		
Triclinic		

TRICLINIC


Paste
Paste
Paste
Paste
Paste
Paste

Cut along solid lines.
Fold along dotted lines and paste where indicated.

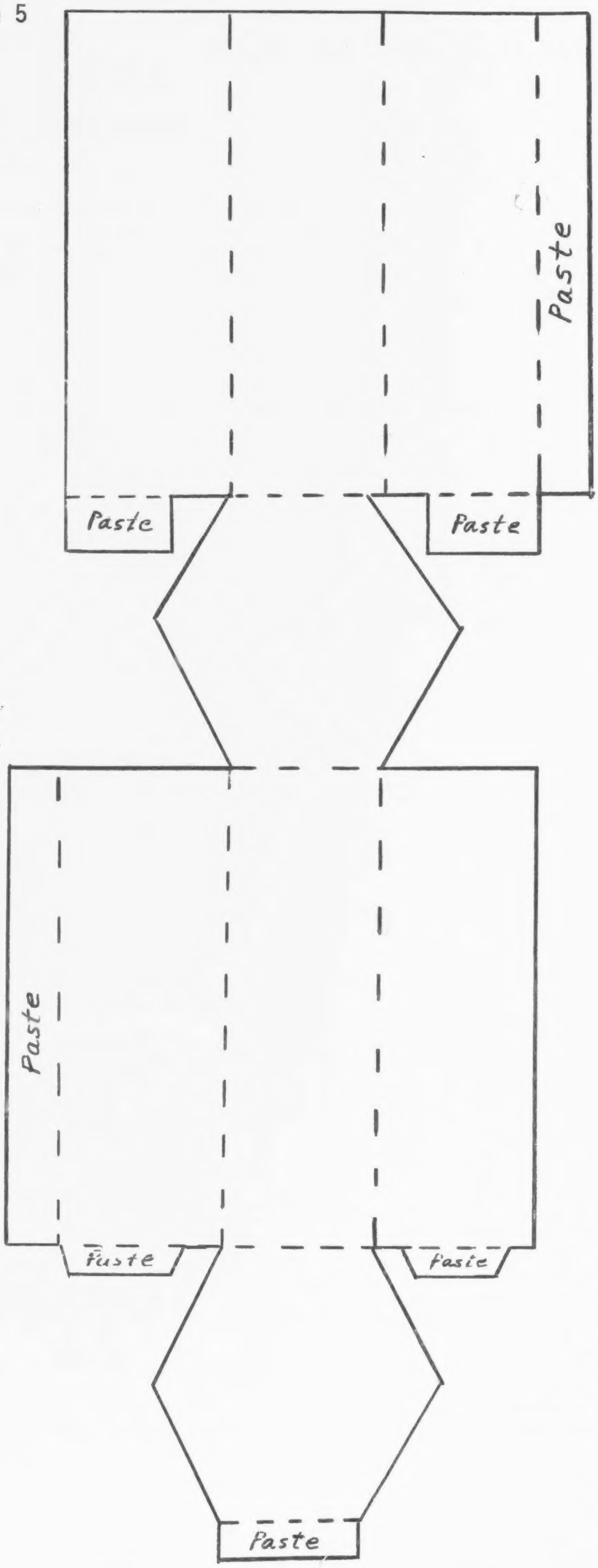
MONOCLINIC


Paste
Paste
Paste
Paste
Paste
Paste
Paste

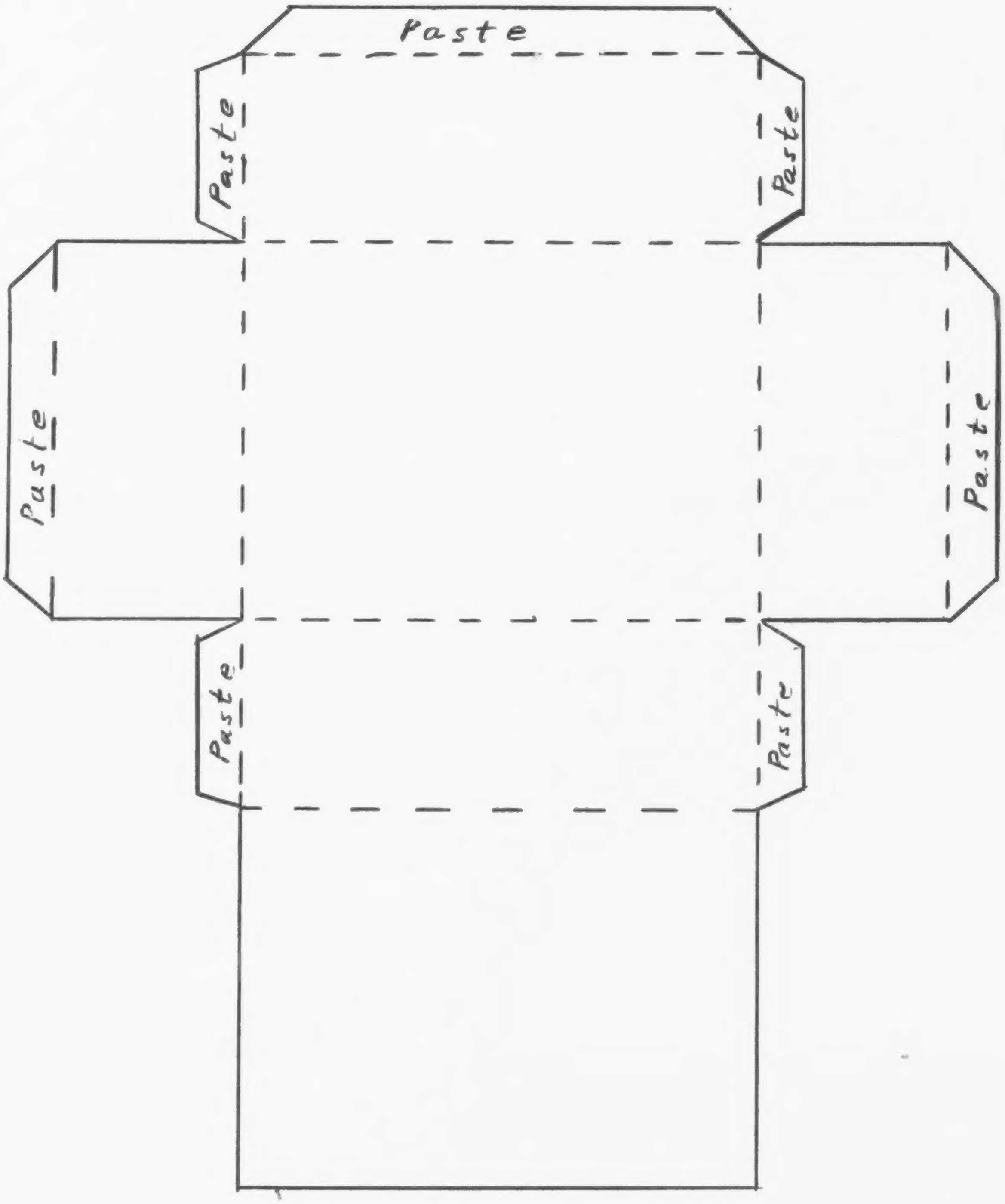
Cut along solid lines.
Fold along dotted lines and paste where indicated.

HEXAGONA'

Cut along solid lines.
Fold along dotted lines and
paste where indicated.

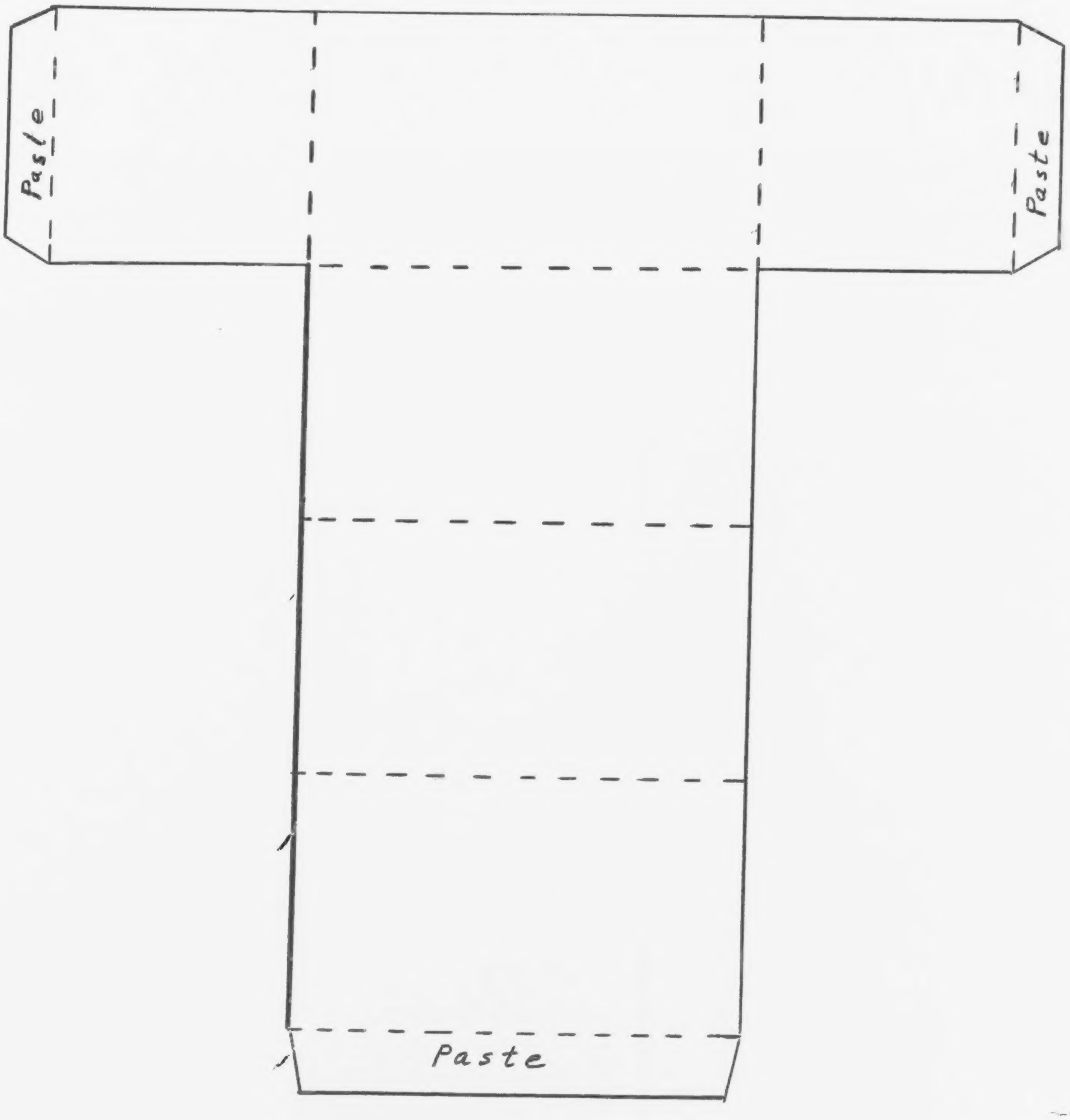

Paste
Paste
Paste
Paste
Paste
Paste
Paste

ORTHOROMBIC


Paste
Paste
Paste
Paste
Paste
Paste
Paste

Cut along solid lines.
Fold along dotted lines and paste where indicated.

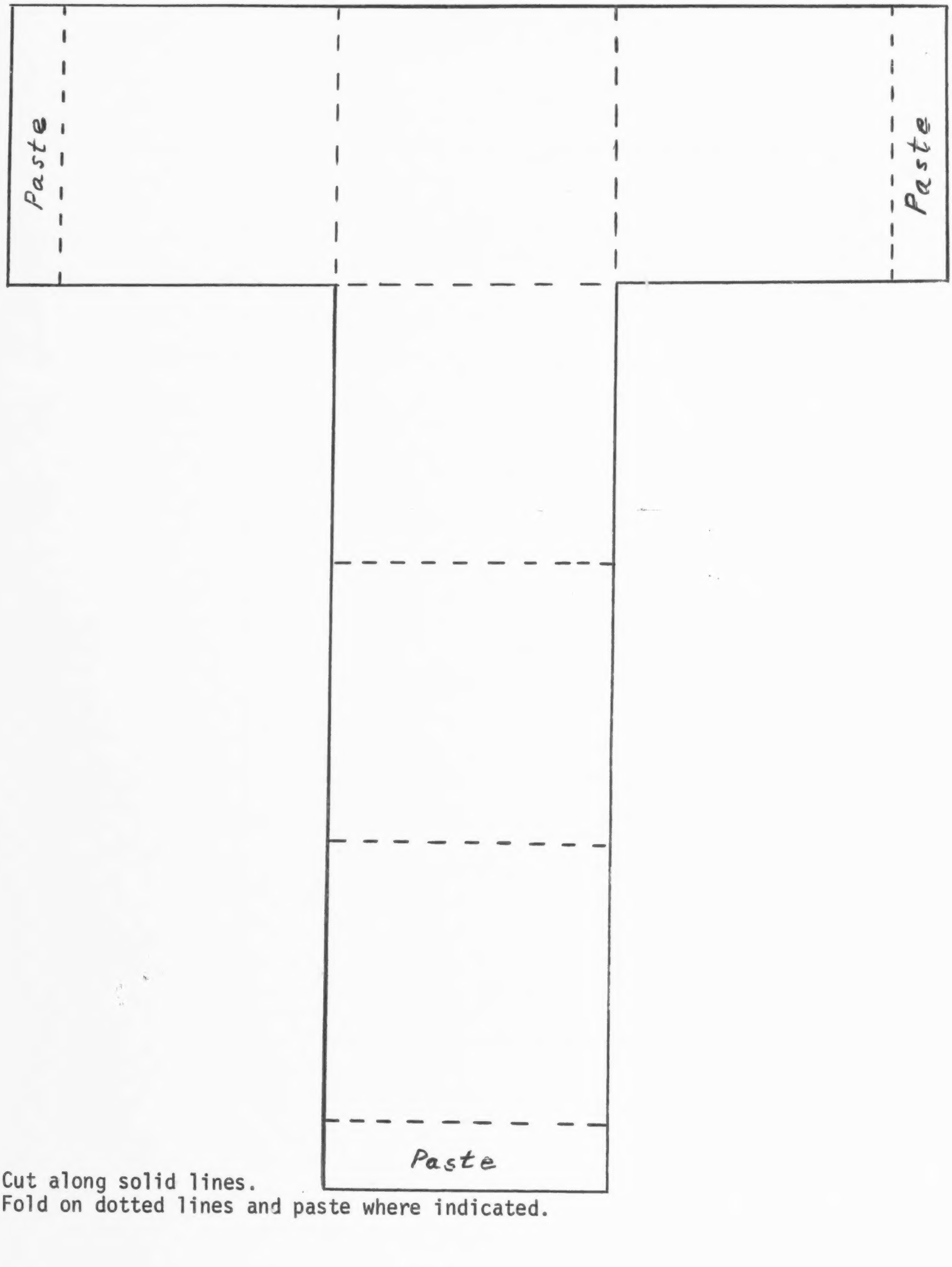
TETRAGONAL


Paste
Paste
Paste

Cut along solid lines.
Fold along dotted lines and paste where indicated.

LESSON 15, Introduction, Page 8

CUBIC


Paste
Paste
Paste

Cut along solid lines.
Fold on dotted lines and paste where indicated.

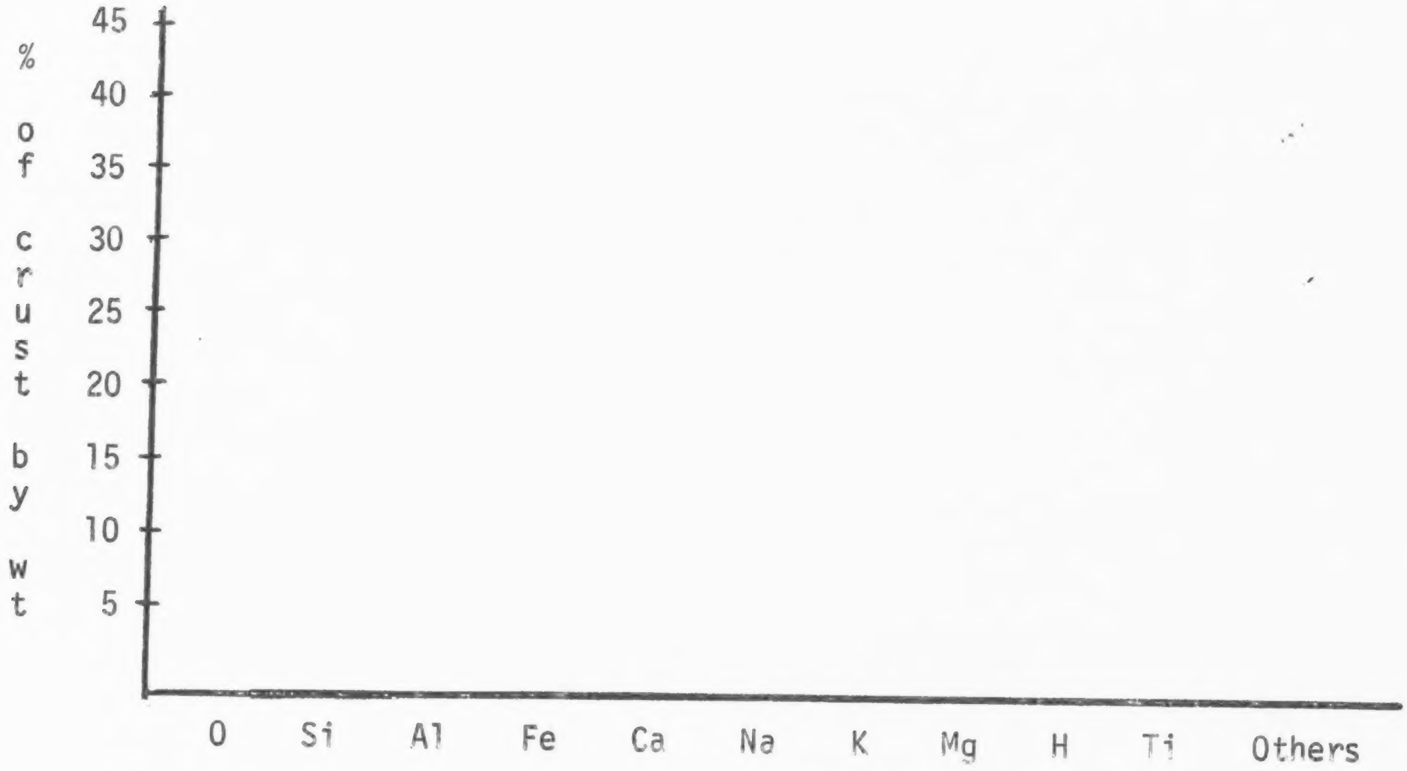
4. Composition of the earth's crust.

Plot the data shown below in a bar graph form. What elements would a rock picked up on the earth's surface be most likely to contain?

TABLE OF COMMON ELEMENTS

Name	Symbol	Percentage of the crust by weight
Oxygen	O	46.60
Silicon	Si	27.72
Aluminum	Al	8.13
Iron	Fe	5.00
Calcium	Ca	3.63
Sodium	Na	2.83
Potassium	K	2.59
Magnesium	Mg	2.09
Hydrogen	H	0.14
Titanium	Ti	0.40

Data taken from: INTRODUCTION TO PHYSICAL GEOLOGY, Longwell and Flint, John Wiley & Sons, Inc., 1963, pp. 31.



5. Crystal growing

MATERIALS:

Bell Telephone microscopes, Prepared slides (salol),
Alcohol lamps, Microprojector, Clean slides
Assorted chemicals

PROCEDURE:

1. Activity:

Either or both chemicals listed below may be used.

Salol

a. Take prepared slides of salol to alcohol lamps and warm them just enough to cause melting to occur.
CAUTION: Salol melts just above room temperature.

b. Place slides in microscope and seed with a very small amount of crystalline salol ; in some cases it may only be necessary to disturb the molten salol with a toothpick in order to initiate crystallization. Take plenty of time and observe crystallization.

Saltpeter

a. Mix super-saturated solution of saltpeter in very small flask. Heat until all crystals are in solution.

b. Place a clean slide on microscope stage, and put one drop of the warm solution on each slide.

c. Watch drop very carefully. Crystallization will begin as solution cools.

2. Teacher demonstration:

Use microprojector after activity to insure that all students have seen the same things. Crystallize the following in order as time permits:

COMPOUNDS	vs.	CRYSTAL TYPES
Sodium Chloride	-	Cubic
Ammonium Dichromate	-	Hexagonal
Ammonium Chlorate	-	Feather Line (Monoclinic?)
Salol	-	Hexagonal
Sodium Thiosulfate	-	Hexagonal
Sodium Nitrate	-	Monoclinic or Triclinic?

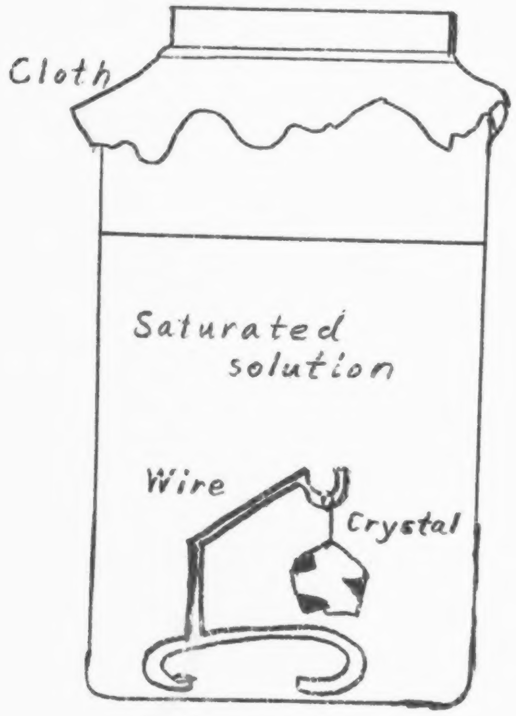
6. Grow Your Own Crystals

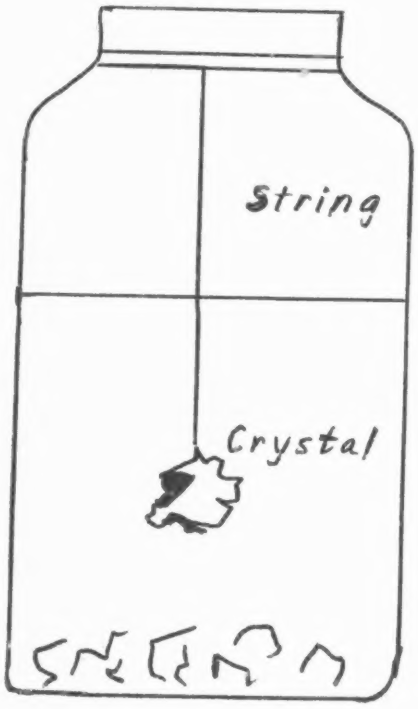
MATERIALS:

Potassium bromate
Distilled water
White cotton thread
Light flexible wire

PROCEDURE:

One of the simplest and finest crystals to grow without special laboratory controls is a large crystal of potassium bromate. There are two steps. First you need a seed crystal. For this, make a solution of potassium bromate in distilled water and place in a dish. Allow the water to evaporate in an atmosphere of about 70° F. Small crystals or seeds will form in the bottom of the dish when all of the water has evaporated. Remove one small "seed crystal" (the proper size seed crystal is 1/8 to 1/4 inch long) and tie some white cotton thread around it. Attach the loose end of the thread to a support over the growing solution. Lower the seed crystal, suspended from the thread, into the saturated solution of potassium bromate and allow the solution to evaporate at room temperature. The solution may evaporate at a slower rate and a more constant temperature in an electric refrigerator.





The seed can be hung from a wire bent into a cobra shape (see drawing). The base of the wire is bent into a sufficiently large circle to prevent tipping. When placed into a saturated solution for growing, the seed should hang an inch or so from the growing bottle. The end of the wire cobra should be below the solution surface. As a covering for the jar, a piece of cloth is held in place with a rubber band. (In place of the wire cobra, the string may be suspended from a cardboard cover over the top of the jar.) Time and evaporation will do the rest of the job.

Almost any substance which crystallizes upon evaporation can be used for crystal growing. When grown, they can be preserved by covering with clear varnish.

For further information see CRYSTALS AND CRYSTAL GROWING (Science Study Series S-7), Holden and Singer, (Doubleday).

LESSON 15

MINERALS

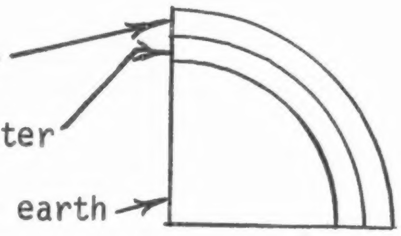
I. Stratigraphic Divisions of the Earth

Nearly 2,000 years ago philosophers divided the earth into three major divisions:

THE ATMOSPHERE - The earth's envelope of air

THE HYDROSPHERE - The earth's envelope of water

THE LITHOSPHERE - The solid material of the earth



All of the materials (solids, liquids, and gases) which are part of the atmosphere, hydrosphere, and lithosphere are combinations of 92 natural elements.

II. Minerals

All of the rocks on the earth are mixtures of minerals which are constructed from 92 naturally occurring elements. The character of the rocks over which we walk determines both the terrain and the economic future of a region. Thus, it becomes important to study the origin, properties, methods of formation, and destruction of the minerals and rocks in order to understand their effect on the region in which they occur.

A. Minerals are defined as naturally occurring substances of inorganic origin with relatively fixed chemical and physical properties.

B. The properties of any given mineral are determined by:

1. The chemistry of the various elements composing the compound.

2. The physical arrangement and size of the atoms involved.

C. The chemical properties of a mineral determine its usefulness to man and its behavior under varying chemical conditions.

III. Crystals

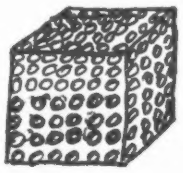
Minerals are compounds; and, as such, they are composed of atoms. The arrangement of atoms determines the shape, color, hardness, density, etc., of the mineral.

A. The great majority of minerals form by adding atoms and molecules to an orderly arrangement called a crystal.

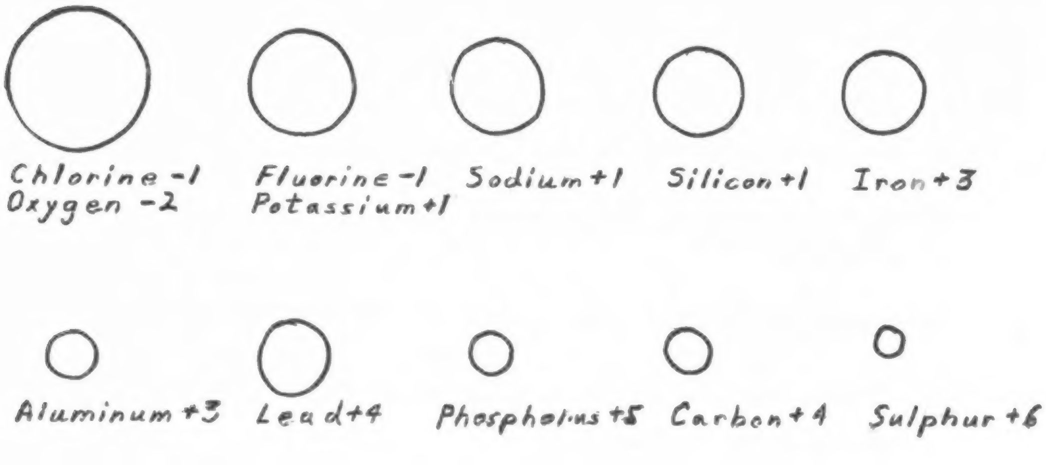
1. A few minerals have no orderly pattern and are said to be amorphous.

2. Crystals grow by adding atoms or groups of atoms about a common center.

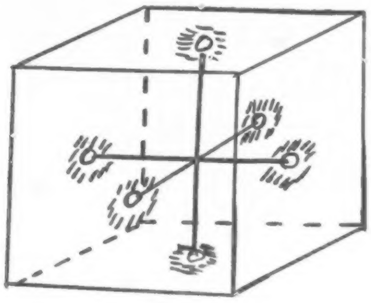
   a. The manner in which the atoms pack together determines the manner in which a crystal grows.



   b. The manner of packing is determined by the various sizes of the atoms involved in forming a crystal.


Chlorine -1
Oxygen -2
Fluorine -1
Potassium +1
Sodium +1
Silicon +1
Iron +3
Aluminum +3
Lead +4
Phospholus +5
Carbon +4
Sulphur +6

   c. Crystal faces grow at right angles to fixed axes. The length of an axis and the angle between axes is established by packing.



D. There are six major groups organized on the basis of axis angles, numbers, and lengths, into which all crystals can be classified:

1. Cubic
2. Tetragonal
3. Orthorombic
4. Hexagonal
5. Monoclinic
6. Triclinic

IV. Properties

A. Normally minerals may be identified by the use of several of their properties.

1. These properties may be divided into two groups:

a. Visible properties

b. Special properties

2. Those properties that are the easiest to determine are used first, and other properties are examined in turn if they are necessary for complete identification.

B. Some 300 minerals occur commonly in nature. The remaining 1,700 are rare and usually require careful work and good technique for positive identification.

V. Visible Properties

A. The so-called visible properties are:

1. Luster
2. Color
3. Streak
4. Cleavage and fracture
5. Hardness
6. Crystal form
7. Specific gravity

VI. Examination of Individual Properties

A. Color

1. Color is a rather unreliable characteristic. Minerals may vary slightly in their composition or have inclusions of other materials. These variations often cause changes in color. Thus, the color of a given sample may vary widely.

2. Weathering (the chemical breakdown of a mineral) often results in a change in color at the surface of a mineral. In these cases the color of a freshly broken surface is usually reliable.

B. Streak

1. Streak is the color of a thin layer of finely powdered mineral.

2. Streak is usually obtained by rubbing the mineral against a "streak plate" made of unglazed porcelain (the back of a ceramic tile).

3. The streak of a nonmetallic mineral is normally colorless or very light while that of a metallic mineral is usually dark.

C. Luster

1. Luster is the ability of a mineral to reflect, refract, and/or absorb light falling on its surface.

2. Minerals normally have one of the following lusters:

   a. dull

   b. pearly

   c. resinous

   d. silky

   e. earthy

   f. metallic

   g. glassy or vitreous

   h. brilliant or adamantine (diamond like)

D. Crystal Form

1. Crystal form usually is a good indicator of a mineral group.

2. Irregularities in growth conditions or the presence of other minerals may affect the crystal shape. When a crystal has more than one form, it may grow in combinations of the two, or in a combined form within a single crystal system.

E. Cleavage and Fracture

1. Cleavage is the breaking of a mineral so that it yields definite flat surfaces.

   a. Cleavage surfaces indicate the crystal structure of a mineral.

   b. Minerals usually split easily (cleave) along certain faces or plains which usually are crystal faces.

   c. Cleavage is described as: Poor, fair, good, perfect, eminent.

2. Fracture is the way in which a mineral breaks when it does not yield along a cleavage or parting surface.
    a. Fractures often reveal the true color of a mineral.
    b. Since fractures are distinctive, they may also aid in identification.
    c. Fracture is described as: Conchoidal, Fibrous, Splintery, Irregular, and Earthy.

F. Hardness

1. The hardness of a mineral is its resistance to abrasion (scratching).
2. The hardness of a mineral is determined by the arrangement of atoms and not just the elements which make up the mineral.

    Example: Diamond and graphite are both carbon.

3. Some minerals exhibit varying hardnesses depending on the direction in which they are scratched. This is often important in identification.
4. The standard scale on which hardness is measured is known as the Mohs' scale.

MOHS' SCALE

(Nemonic Jingle)	Hardness	Test Mineral
To	1.	Talc
Go	2.	Gypsum
Calling	3.	Calcite
Fast	4.	Fluorite
At	5.	Apatite
Fine	6.	Orthoclase
Quarters	7.	Quartz
Take	8.	Topaz
Care	9.	Corundum
Driving	10.	Diamond

HARDNESS OF SOME USEFUL EVERYDAY STANDARDS

2.5	Fingernail
3.0	Penny
5.5	Glass or knife blade
6.5	Steel file

G. Specific Gravity

1. The relative weights of minerals can be judged roughly by "hefting" two pieces of approximately the same size.

2. Specific gravity is a measure of a mineral's weight in relation to an equal amount of water.

$$\frac{\text{Dry weight}}{\text{Net Weight}} = \text{Specific Gravity}$$

Net Weight = Dry weight - wet weight

VII. Special Properties

A. Certain minerals have special properties which make them unique.

B. Some typical special properties include:

Magnetism
Piezoelectricity
Fluorescence
Phosphorescence
Radioactivity
Temperature of fusion
Optical properties - index of refraction birefringence

VIII. Special Tests

A. In certain cases when the mineral being identified is one of the rare group or when two minerals have very similar properties, it is necessary to resort to special tests.

1. Special tests include checking for special properties and certain chemical tests.

2. The simple chemical tests include:

   a. Acid solubility and/or reaction

   b. Color tests

3. Blowpipe - oxidation and reduction

4. Flame tests - color of solution in flame

5. Bead tests - oxidation and reduction

6. Open tube and closed tube for color and odor.

IX. North Carolina - Mineral Supermarket

North Carolina is unusual in that there are probably more different minerals found within its borders than in any other political unit of equal size. More than 300 minerals have been found in North Carolina, and many occur in considerable quantities. Lists and locations of numerous collecting sites can be found in THE DIVISION OF MINERAL RESOURCES, CIRCULAR 16.

LESSON 16, Introduction

IGNEOUS ROCKS AND ROCK FORMING MINERALS

Objectives:

1. To develop a concept of the rock cycle in terms of function.
2. To recognize the rock forming minerals and understand how they may combine to form different types of rock.
3. To understand igneous processes in general terms including formation and activity.
4. To recognize igneous land forms in terms of structure and in terms of the history they represent.

References:

1. THE EARTH - SPACE SCIENCES, Chapters 22 and 24.
2. FOCUS ON EARTH SCIENCE, Chapters 4 and 5.
3. INVESTIGATING THE EARTH, Chapters 2 and 15.

Special References:
Wolfe, *et al*. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 4, 5, and 6.
Bullard. VOLCANOES: IN HISTORY, IN THEORY, IN ERUPTION (University of Texas Press, Austin Texas).
Pirsson and Knopf. ROCKS AND ROCK MINERALS (John Wiley & Sons, New York).
Gilluly, *et al*. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company), Chapter 18.
Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 4 and 5.

Activities:

1. Investigating rocks and minerals
   ESCP 2-2 — Text 39
   Teacher's Manual 70-74

2. Investigating rocks from the cores of mountains
   ESCP 15-1 — Text 332
   Teacher's Manual 409-410

3. Investigating igneous rocks
   ESCP 15-4 — Text 337
   Teacher's Manual 415-416

4. Laboratory exercise:
   Identification of Rock Forming Minerals

   Using the table and specimens provided, identify each and compare one with another. Refer to the material in Lesson 15 if necessary. When you have completed the identification, take a hand lens and try your hand with some large grained igneous rocks. (See table on following page.)

NAME	LUSTER	COLOR	STREAK	HARDNESS	CRYSTAL FORM	FRACTURE	CLEAVAGE	SPECIFIC GRAVITY	COMMENTS
Quartz No. _____	Vitreous	Colorless white to all colors; transparent to translucent	Colorless	7	Hexagonal	Conchoidal	None	2.65	Terminated hexagonal prisms striated perp. to length often massive
Orthoclase No. _____	Glassy	White, pink, yellow, brown, colorless	Colorless	6-6.5	Triclinic	Conchoidal	Good 2 at 90^0	2.55-2.63	K-Feldspar
Plagioclase No. _____	Glassy	White, yellow, reddish gray to black	Colorless	6	Triclinic	Conchoidal	2 good at 94^0	2.6-2.8	Series of minerals
Biotite No. _____	Glassy	Dark brown to black; opaque to translucent	Colorless	2.5-3	Monoclinic	None	Perfect basal	2.8-3.4	Yielding thin flexible sheets (usually dark in color)
Muscovite No. _____	Pearly to glassy	White, yellow, colorless to green	Colorless	2-2.5	Monoclinic	None	Perfect basal	2.8-3.0	Yielding thin flexible plates
Hornblende No. _____	Glassy	Green to black opaque	Colorless	5-6	Monoclinic (Prismatic)	Sub-conchoidal to uneven	Prismatic	2.0-3.4	Often striated giving woody texture. Crystals usually long and thin
ugite No. _____	Glassy	Black	Colorless	5-6	Monoclinic (Prismatic)	Uneven	Perfect prismatic	3.2-3.4	Crystals tend to be stubby
alcite No. _____	Glassy	Colorless white to pale tints	Colorless	3	Hexagonal	Conchoidal	Nearly perfect rhombohedral	2.71	Effervesces in dilute HCl
hlorite o. _____	Pearly	Green to bluish green	Colorless	2-2.5	Monoclinic	None	Perfect	2.6-3.0	Usually distinguished from mica by color; from talc by hardness
livine o. _____	Glassy	Green, gray to brown	Colorless	6.5-7	Orthorombic	Conchoidal	One fair; one poor	3.3-3.4	Usually transparent to translucent sometimes in granular masses

LESSON 16

IGNEOUS ROCKS AND ROCK FORMING MINERALS

I. Rocks are classified according to their origin.

  A. Origin can be determined from evidence found in the rocks and the circumstances in which they are found.

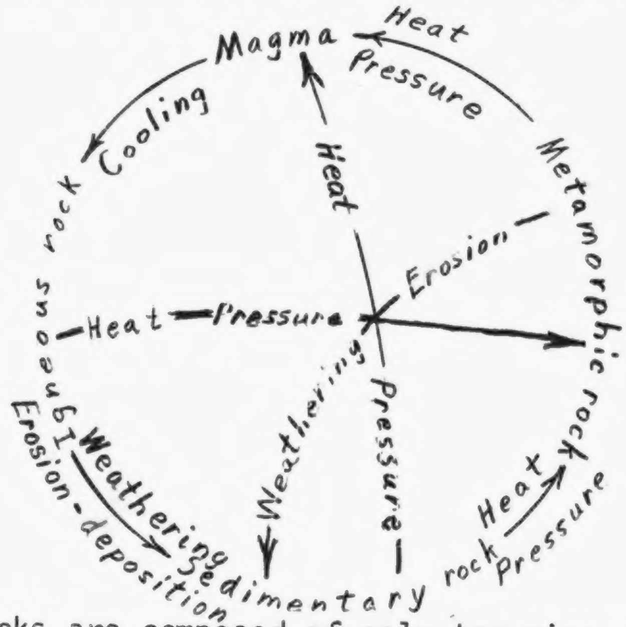
  B. There are three major types of rocks.

    1. Igneous rocks (formed from molten material beneath or on the earth's surface).

    2. Sedimentary rocks (fragments of rocks which have been transported to a new area, deposited, and cemented to form a new rock).

    3. Metamorphic rocks (changes in rock caused by heat and/or pressure applied to any type of previously existing rock may produce metamorphic rock).

II. Rocks developed from magma are eroded, transported, deposited, and metamorphosed, in an endless series of events known as the Rock Cycle.


Magma
Heat
Pressure
Cooling
Igneous rock
Heat
Heat
Pressure
Erosion
Metamorphic rock
Weathering
Erosion-deposition
Weathering
Pressure
Heat
Pressure
Sedimentary rock

III. Over 90% of all rocks are composed of only ten minerals. They are known as the "major rock forming minerals" and are listed below:

  A. Feldspar (several kinds are found, color varies).

    1. Orthoclase ($KAlSi_3O_8$) - common in granite.

    2. Plagioclase ($NaAlSi_3O_8$) - common in most other igneous rocks.

  B. Quartz (SiO_2) - very common and very resistant to weathering and erosion.

  C. Mica

    1. Biotite (black)

        2. Muscovite (white)

    D. Pyroxenes (most common is Augite)

    E. Amphiboles (most common is Hornblende)

    F. Calcite ($CaCO_3$) - found in limestone and marble

    G. Chlorite (mica rich silicate)

    H. Olivine $(MgFe)_2SiO_4$

    I. In igneous rocks, the composition coupled with the grain size and texture are used to determine a name.

IV. Igneous rocks form from molten materials originating far beneath the earth's surface.

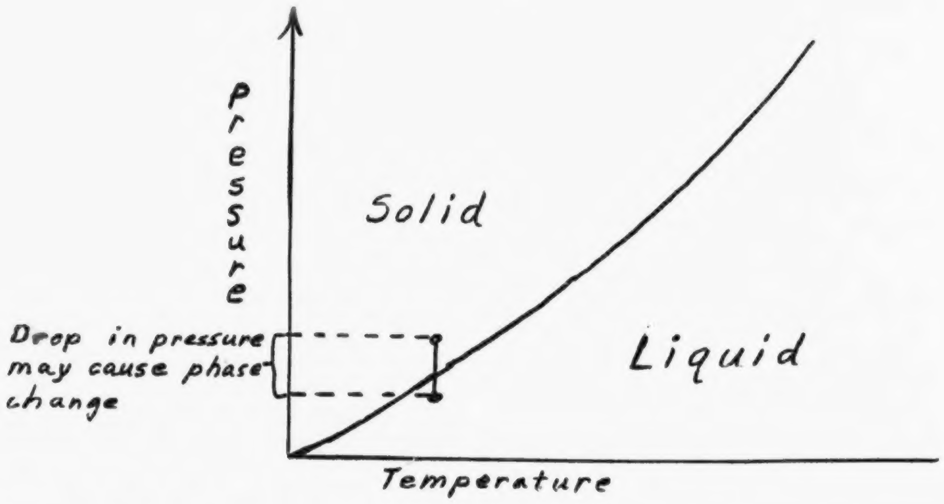
    A. The hot liquid magma, which is the source of igneous rock, comes from deep within the earth's crust.

        1. The heat which is necessary to melt the rocks is believed to come from radioactive elements within the rocks.

        2. Rocks are kept solid at depth due to the tremendous pressures bearing on them.

        3. If the pressure is released by shifting of the rocks, the rocks may become liquid due to the extreme temperatures occurring at this depth beneath the earth's surface.

        4. Thus, in the event of a pressure release, a body of magma (liquid rock) may form.



    B. Bodies of magma may work their way to the surface in several ways.

        1. Overlying rocks are cracked and broken due to the upward pressure exerted by the magma.

        2. Overlying rock may also be removed by melting.

C. Igneous magmas which reach the surface are termed extrusive igneous rocks.

   1. Magma that reaches the surface is called lava.
   2. Extrusive igneous rocks form volcanoes and lava flow.
   3. These extrusive rocks are usually very fine grained or glassy due to rapid cooling.

D. Igneous rocks that do not break through the surface are termed intrusive igneous rocks (also called Plutonic).

   1. These rocks show varying grain size depending on their rate of cooling.
   2. Intrusive igneous rocks are often exposed at the surface (after cooling) by erosion of the overlying rocks.

E. Differences in the rate of cooling produce differences in crystal size on which texture classification is based.

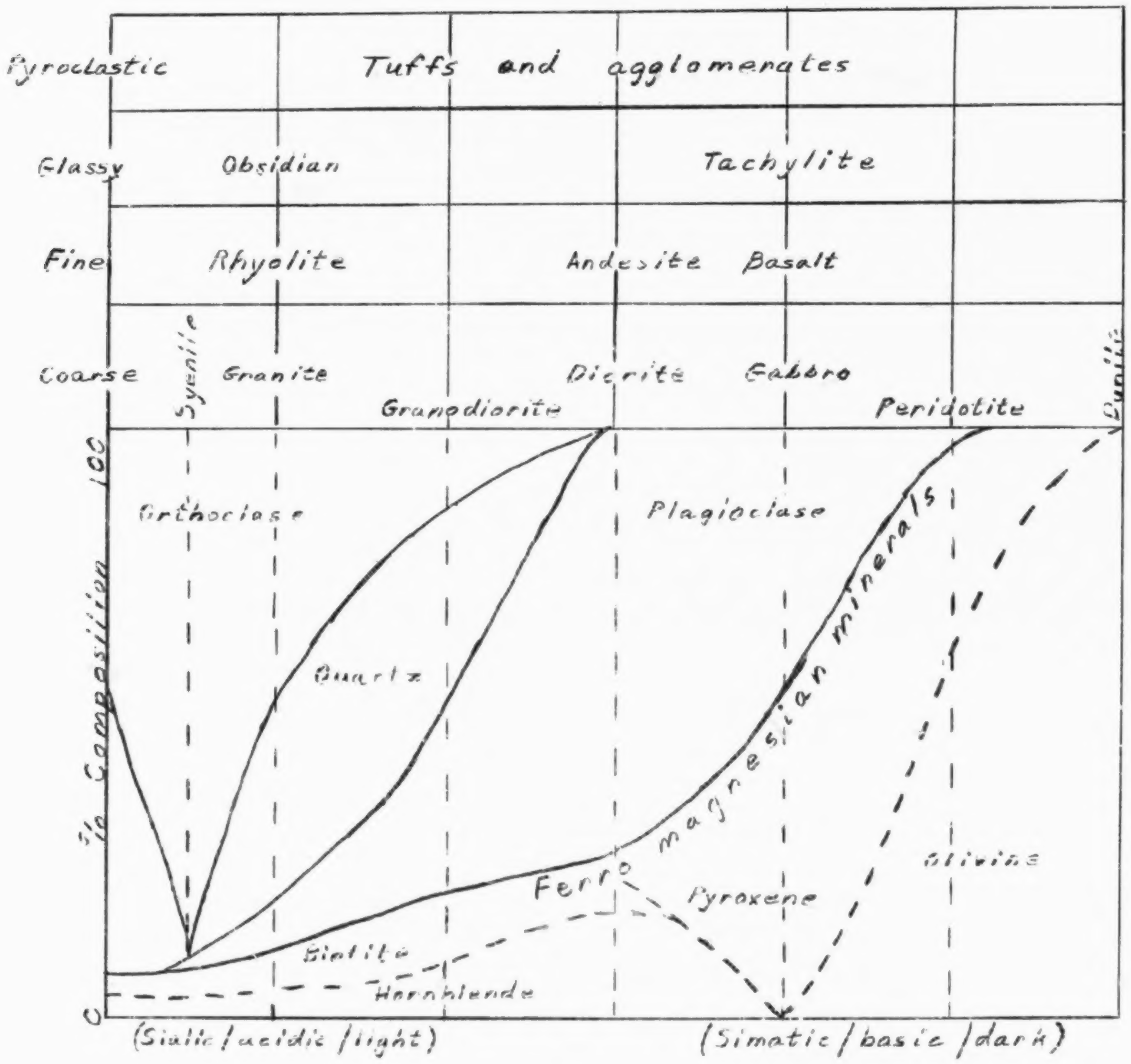
   1. Intrusive rocks that cool slowly become very coarse grained. These rocks are usually deep in the earth's crust at the time of cooling.
   2. Intrusive rocks that cool more rapidly are finer grained. These rocks are usually nearer the surface at the time of cooling.
   3. Some intrusive and extrusive rocks cool slowly at first and more rapidly later on. This produces a texture of mixed grain size called a porphyry (porphyritic texture).
   4. Extrusive igneous rocks usually cool rapidly because of their exposure at the surface. This results in an extremely fine grained or even glassy rock.

F. Igneous rocks of special interest.

   1. Pegmatite - very coarse grained variety of granite (found in North Carolina).
   2. Pumice-Rhyolitic lava that cools rapidly trapping gas bubbles within the rock (very light weight, will usually float in water).

G. Types of intrusive igneous rock (classified according to their composition and texture).

   1. Light colored rocks (high in silica content) termed silaceous, felsic, or acidic.
   2. Dark colored rocks (contain iron and magnesium and less silica) termed mafic, basaltic, or basic.
   3. Texture depends on the rate at which the rock cools.



V. Igneous intrusions.

A. Types of intrusive bodies.

1. Batholiths - a large body of intrusive igneous rock whose lower limit is indefinite. Batholiths usually form the core of mountain systems (see A in following diagram).

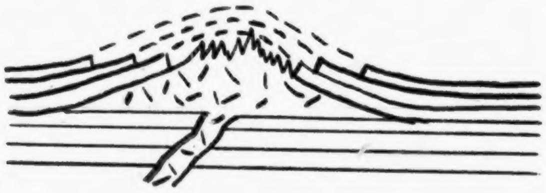
    a. Due to their volume, batholiths cool slowly and the grain size varies from fine grained rocks near the edges to larger grained rocks near the center.

    b. The Idaho Batholith is an example of this.

2. Stock - a smaller body of intrusive igneous rock, smaller than 40 square miles (see B in following diagram).

3. Laccolith - occurs when intruding magma moves between existing layers of rock causing them to arch upward.

a. The heights involved may reach 1,000 feet over an area of 100 square miles. Laccoliths have definite floors (see drawing below and C in following diagram).



b. The rocks are similar to those of a batholith and vary in texture according to the size of the mass.

4. Sills - sheet-like mass of magma that flows between existing layers of rock forcing the layers apart but not doming them as in the case of the laccolith (see D in following diagram).

   a. The walls of a sill are roughly parallel with those enclosing layers of rock.

   b. Cooling is rather rapid along the contact zones and slower nearer the middle.

5. Dikes - a mass of magma that fills a crack or fissure in existing rock structure. Dikes are often outgrowths from a larger igneous intrusive body (see E in following diagram).

   a. Cooling of the magma in a dike is similar to that in larger masses.

   b. Because of the large amount of gas and water vapor that is often present, magmas may remain fluid for long periods of time. Thus, very large crystals are often found associated with dikes.

6. Volcanic necks or plugs - the magma passageway of a volcano may cool forming a solid plug. These plugs are often exposed by erosion. An example of this is shiprock. (See F in following diagram.)

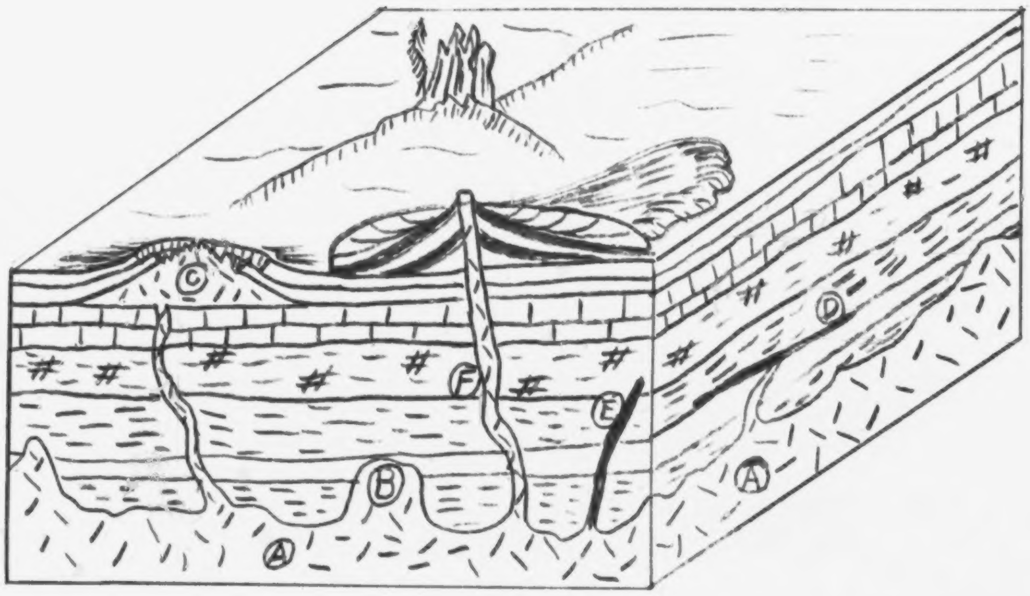
7. Metallic ores and mineral deposits in igneous rocks.

   a. The ores of metals that are valuable to man are normally found in association with igneous rocks.

   b. As the magma moves toward the surface, various materials crystalize out at various temperatures and pressures. The minerals collect in a crack or crevice of the cooling igneous magma.

   c. A mass of material collected in a crack or crevice is called a vein. Often small quantities of the mineral are present in the rocks surrounding a vein (may be metallic ore or gem material).

   d. A system of veins may be referred to as a lode.


C
D
F
E
B
A
A

LESSON 17, Introduction

EXTRUSIVE IGNEOUS ROCKS AND VOLCANOES

Objectives:

1. To understand extrusive igneous processes and the land forms they create.
2. To be able to recognize extrusive materials and relate them to the process that created them.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 22.
2. FOCUS ON EARTH SCIENCE, Chapter 5.
3. INVESTIGATING THE EARTH, Chapter 16.

Special References:

Wolfe, *et al*. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 5 and 6.

Bullard, Fred M., VOLCANOES, IN HISTORY, IN THEORY, IN ERUPTION, (University of Texas Press; Austin, Texas).

Gilluly, *et al*. PRINCIPLES OF GEOLOGY, (Freeman Publishing Company), Chapter 18.

Holmes, Arthur, PRINCIPLES OF PHYSICAL GEOLOGY, (Ronald Press, New York), Chapter 5.

Pirsson and Knopf, ROCKS AND ROCK MINERALS.

Activities:

1. Formation of Volcanic "Glass" Vs. Crystallization
   ESCP 15-5 Text 340
   Teacher's Manual 418-419

LESSON 17

EXTRUSIVE IGNEOUS ROCKS AND VOLCANOES

I. Volcanism-- Igneous extrusive rocks

   A. The term volcanism covers all types of volcanic activity.

      1. Processes that give rise to magma and cause its movement within the earth.

      2. Expulsion of gases, lava, and solid materials from openings in the earth's crust.

   B. Many myths and legends center around the evidence of volcanism. VULCAN - The ancient god of fire (Roman).

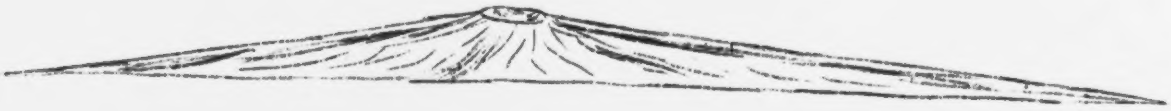
II. Extrusive Volcanism

   A. Volcanoes are mountains or hills formed around a vent in the earth's crust through which hot materials are expelled.

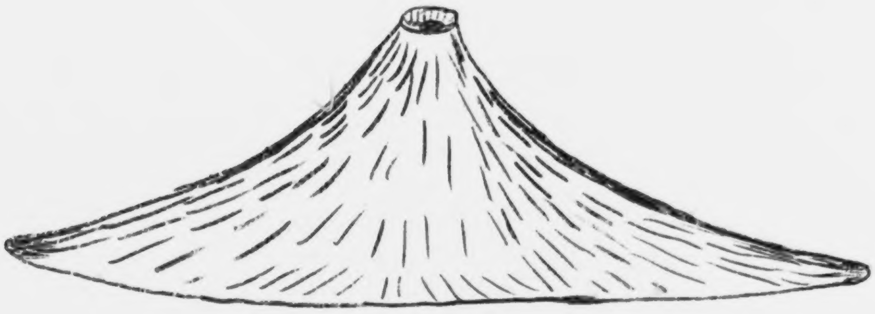
      1. The type volcano is determined by the type of cone. A cone is the name given for the solids built up around a vent.

      2. The type of cone developed depends upon the chemical and physical nature of the material being ejected.

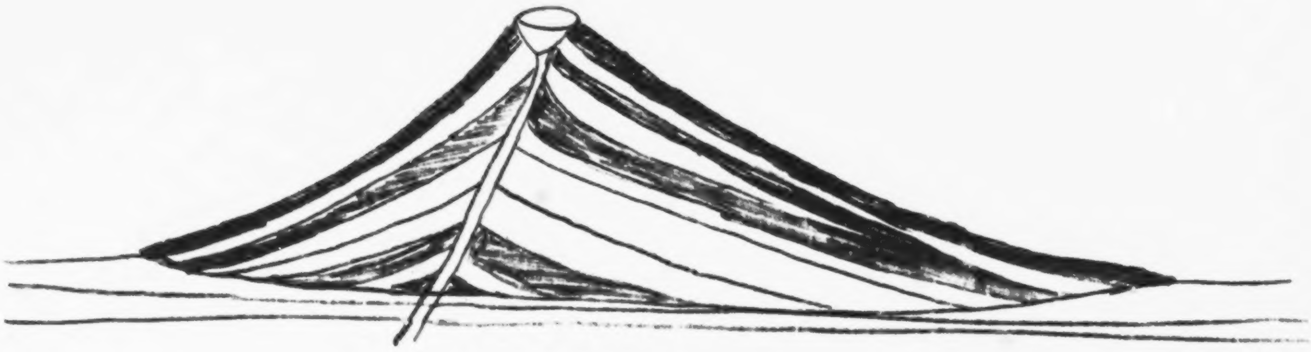
         a. Shield Cone - Basaltic lavas flow freely, forming broad flat cones with large bases and gentle slopes. (Example: Hawaiian Islands)



         b. Cinder Cones - The ejection of sharp angular fragments results in a cone with very steep sides because the particles interlock.



c. Silica rich lavas are viscous and result in cones with steep sides. Because the lava hardens before it has a chance to spread, steep-sided cones are formed. Lava of this character may form Composite Cones if solid materials are also embodied in the cone.



B. Types of Eruptions

1. Quiet Volcanism - This type of volcano is non-explosive.

   a. Lava is fluid (basaltic) and gives off gases readily.

   b. Spreads quickly to form a shield-type cone.

2. Explosive Volcanism - Some volcanoes explode with unbelievable violence. The eruption is often preceded by loud rumblings and earthquakes which open fissures, drain lakes, and create hot springs. (Example: Krakatoa)

3. Intermediate Volcanoes - This variety of volcano is a combination of the quiet and explosive types, being sometimes quiet, sometimes explosive, and sometimes a combination of both.

4. Fissure Eruptions - This type of extrusive activity does not build a cone. Floods of very fluid lava are extruded, forming lava plains and lava plateaus. (Example: Columbia Plateau) Fissure eruptions have occurred in modern times in Iceland.

VI. Products of Eruptions

A. Gases and vapors:

1. Steam is the most abundant vapor that escapes.

2. Fissures or holes from which gases escape - fumaroles.

3. Hydrochloric and hydrofluoric acid, sulfur oxides, and boron compounds rise with the steam.

4. Vapors also include gaseous metals. These are normally deposited on or near the surface as incrustations.

5. Other gases - CO_2, CO, CH_4, H_2NH_4, O_2, He, and Ar.

6. Fumaroles are common in areas of active volcanoes and are found in areas where no surface activity is present.

B. Fragmental material from large chunks to dust size.

1. Volcanic bombs form when liquid solidifies during its flight through the air.

2. Blocks may weigh several tons.

3. Intermediate size particles are called lapilli or cinders.

4. The finest particles are ash and dust.

C. Liquid material - lava.

1. Generally issues from a fissure.

2. Temperature of lava is about 1,000° C. (1,830°F.)

3. The rate and method of cooling determine the lava type.

Blocky (aa) Lava - Lava cools at the surface while the under part is very hot. Crust breaks into jagged chunks as the liquid moves under it.

Pahoehoe - Lava solidifies with smooth, ropy appearance.

Pillow Lava - Develops when basaltic lava flows into water developing a structure resembling a pile of pillows.

4. Condensed water sometimes mixes with volcanic ash and dust to produce thick streams of mud - mud torrents.

VII. Extrusive rocks occur as lava flows, volcanic ejecta, and volcanic ash.

A. Rhyolite and Basalt - fine grained lavas.

1. Rhyolite is the acidic (high silica) form.

2. Basalt is the basic (low silica, high iron and mangnesium) form.

B. Obsidian - glassy rock formed when extrusion cools very fast.

C. Pumice - rock which cooled rapidly as a froth.

D. Scoria - extrusive basaltic lava which cooled forming bubbles.

E. Tuft and Breccia - formed from dust, ash, and fragments thrown out by the volcano. (Tuft is fine-grained; breccia, larger.)

LESSON 18, Introduction

WEATHERING

Objectives:

1. To gain an understanding of the processes by which rocks are broken down.
2. To develop a concept of the formation of soils.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 25.
2. FOCUS ON EARTH SCIENCE, Chapter 6.
3. INVESTIGATING THE EARTH, Chapter 12.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 7.
Holmes, Arthur, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 14.
Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapter 4.

Activities:

1. Investigating Products of Weathering
   ESCP 12-3 Text 274-275

2. Activity: Steel Wool Oxidation
   ESCP 12-2 Text 273
   Teacher's Manual 333-336

3. Flocculation Demonstration
   ESCP 12-4 Teacher Manual 336-337

4. Soil Profile: Find a road cut, stream bank, or other exposure and sketch the soil profile to scale showing the various horizons.

LESSON 18

WEATHERING

I. Introduction

- A. Weathering is the breakdown of existing fresh rock.
- B. Weathering is also a process of adjustment to changes in conditions.
  - 1. Rocks that become exposed at the surface are subjected to conditions different from those under which they were originally formed.
  - 2. Heat from the sun, moisture, frost, and wind action contribute to the breakdown of rock into small pieces.
  - 3. The final end product of all weathering is soil.

II. The process of weathering can be divided into two classes:

- A. Mechanical Weathering - Rocks may be broken down by mechanical weathering into small pieces without undergoing any chemical change.
  - 1. Frost wedging - Water seeps into cracks in a rock and may freeze. Freezing water expands and splits the rock.
    - a. This process is capable of prying off large blocks from great masses of rock.
    - b. Frost wedging's greatest effect is through the constant chipping off of small grains of rock as water seeps into tiny crevices and freezes.
  - 2. Exfoliation - Causes flakes to peel off exposed rock surfaces.
    - a. Most exfoliation occurs in humid climates and is caused when certain minerals absorb water and expand.
    - b. This coupled with unequal expansion of the rock's outer surface and its interior causes curved flakes to split off the rock.
  - 3. Plants - Plant roots growing down in cracks in rocks cause the rocks to split (root wedging).
  - 4. Animals - Burrowing animals expose fresh rock to the agents of weathering and smaller animals such as earthworms loosen the soil allowing free access of water and air to fresh rock.

B. Chemical Weathering - Chemical changes that cause rock to disintegrate.

1. Reactions take place between minerals in the rock and CO_2, O_2, and H_2O.

2. The products of mechanical weathering are merely smaller fragments of the original rock. Mechanical weathering contributes to chemical weathering by increasing the surface area that can be attacked by chemical weathering agents.

3. There are several types of chemical weathering, each producing a product different from the original rock.

   a. Carbonation - action of carbon dioxide, CO_2, alone has little effect, but $CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid) which dissolves carbonate compounds (calcite, limestone).

   $$CaCO_3 + H_2CO_3 \rightarrow \underset{\substack{\uparrow \\ \text{Water Soluble}}}{Ca(HCO_3)_2}$$

   b. Oxidation - combination with oxygen.

      (1) Especially effective on iron bearing minerals.
      (2) $$\underset{\text{Pyrite (insoluble)}}{2FeS_2} + 2H_2O + 7O_2 \rightarrow \underset{\substack{\uparrow \\ \text{(Water Soluble)}}}{2FeSO_4} + 2H_2SO_4$$

   c. Hydration - combination with H_2O.

      (1) Hydration causes swelling - thus, exfoliation is due in part to this process.
      (2) $$\underset{\text{(hematite)}}{Fe_2O_3} + H_2O \rightarrow \underset{\text{(limonite)}}{Fe_2O_3 \cdot H_2O}$$

   d. Leaching - dissolving materials from soil and rock.

   e. Plants and animals produce acids that aid in weathering.

C. Over long periods of time all types of rocks were broken down and the surface of the earth accumulated this debris.

1. Mantle rock - detached rock fragments on the land surface.

2. Bedrock - solid rock beneath the mantle rock.

3. Large boulders separated from the bedrock are called residual boulders.

III. Factors affecting the rate of weathering.

  A. Nature of the rock - the composition of some rocks is more susceptible to erosion and weathering.

    1. Quartz is very resistant to chemical weathering.

    2. Calcite can be dissolved easily.

    3. The type of cement in sedimentary rocks affects the rate of weathering.

  B. Size of particles - smaller particles weather faster. (Greater area exposed to weathering.)

  C. Climate

    1. Weathering is slower in dry climates.

    2. Weathering is greatest in humid, warm areas.

    3. Relics brought from Egypt (well preserved after 2000 years) have weathered away very rapidly in England's moist climate.

  D. Topographic Conditions

    1. Altitude.

    2. Slope of the land - steeper slopes allow more removal by erosion thus exposing new surfaces to weathering.

    3. Exposure to rain and sun.

IV. Soil is a collection of natural bodies on the earth's surface containing living matter and capable of supporting plant life.

V. Type of soil depends on several factors.

  A. Parent material - different materials break up in different ways.

  B. Climate

  C. Topography

  D. Action of organisms

  E. Combinations of these factors produce a great variety of soil types.

VI. Soil is also classified according to source.

A. Residual soil - still in the location of its formation.

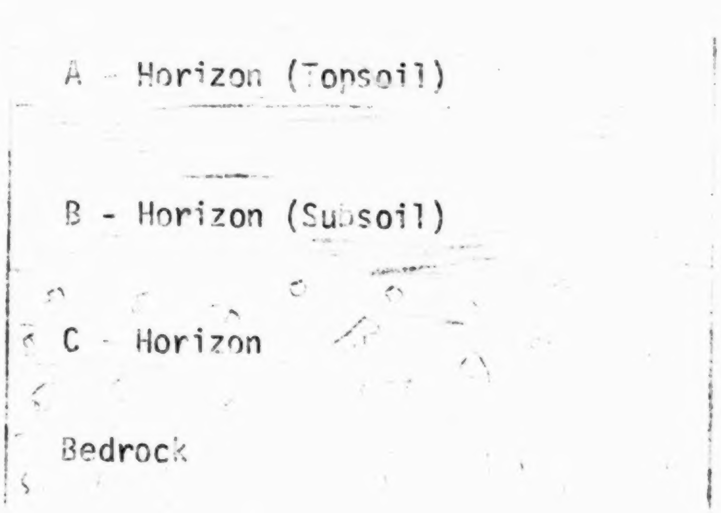
B. Transported soil - has been eroded from source area and deposited in another area.

NOTE: Residual soils rest on the bedrock from which they were derived. Transported soils have been carried to their present location by wind, running water, or glaciers. Their character depends on the transporting agent.

VII. One feature common to all soils is the Soil Profile.

A. Profile is the name given to successive layers called horizons.

B. Horizons are labeled as they grade to bedrock.



Topsoil contains humus (decaying plant and animal material). Color is usually dark.

Subsoil contains more iron oxide and clay. Color usually reddish or brownish.

Weathered parent material and loose, partially decayed rock.

VIII. Soil conservation is becoming increasingly important.

A. Continuous erosion exposes subsoil, which is poor for crop growth.

B. Time is required for soil formation. The best estimate indicates that about 500 years are required to produce one inch of topsoil.

C. Careless practices by man upset the balance of nature and increase erosion.

1. Forest fire
2. Poor farming methods
3. Careless mining practices (Example: Kentucky)

D. Conservation Methods

1. Contour plowing - plow along contours of the land.
2. Terracing - steps are built to reduce the steepness of slope.
3. Strip cropping - plant alternate rows of cover crops and row crops.
4. Planting vegetation on unused land.
5. Alternating crops (crop rotation) helps to prevent the depletion of minerals from the soil by certain crops.
6. Wind breaks to prevent wind erosion.
7. Fertilization of land also helps return minerals to the soil.

LESSON 19, Introduction

EROSION AND RUNNING WATER

Objectives:

1. To develop a concept of gravity's role in erosion.
2. To understand the mechanisms involved in stream erosion.
3. To understand the behavior of a stream in eroding the land surface and the features developed by its actions.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 16.
2. FOCUS ON EARTH SCIENCE, Chapter 13.
3. INVESTIGATING THE EARTH, Chapter 12.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 8, 13, and 14.
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 22, 23, and 24.
Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapters 5, 11, and 12.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 17, 18, and 19.

Activities:

1. Investigating Factors in Stream Erosion
   ESCP 12-6 Text 279
   Teacher's Manual 339-340

2. Investigating Change in Rocks (Stream Abrasion)
   ESCP 1-4 Text 19
   Teacher's Manual 41-44

3. Take a short walk to the stream nearest your classroom. Using your material from topographic maps, make a simple map showing the stream and its valleys. Try to include at least one turn. Using sticks, styrofoam balls, or some other floating object try to locate, time, and map the various currents. Hint: Vectors are handy here. They represent speed or force and indicate the direction of force or motion. Do the currents change? Why? Does gradient have any effect? How about meanders?

4. Teacher's notes for field-lab investigation on the rate of surface erosion.

PROBLEM: How much material is carried away by __________ Creek each year?

SOLUTION in two stages:
1. Determine discharge of ________ Creek.
2. Determine load of ____________ Creek.

Note on teaching method: Students should be questioned in such a way as to lead them toward the desired solution. The actual math of part three should be avoided with all but the more advanced groups.

Need to know: Amount of material being removed from basin. (Find load of stream on a per year basis.)

Part I. Gauge stream to determine discharge.

A. Materials:

1. Rope marked in one-foot segments.
2. Stadia rod. (Rod 10 feet long marked in feet and inches)
3. Graph paper in one-foot units.
4. Wood floats.
5. Tape measure (rope may be used).
6. Stopwatch (or watch with sweep second hand).

B. Procedure:

1. Stretch rope across stream (level).
2. Using rod, measure depth of stream at one-foot intervals (to nearest inch).
3. Chart data to obtain cross-section of stream.
4. Determine cross-sectional area of stream to nearest square foot (eyeball method).
5. Measure time required for float to travel 100 feet in section of stream where cross section was measured. (Use average of three runs.)
6. Hold data for return to lab.

C. Calculations to be made in lab.

1. Cross sectional area = (ft.$)^2$

2. Velocity of stream = Run 1 + Run 2 + Run 3 = $\frac{\Sigma}{3}$ =

(ft./sec.)

(ft/sec)(60 sec/min)(60 min/hr) =

(ft/hr)(1/5,280 mile/ft) = (velocity miles/hour)

3. Discharge = (crossectional area ft^2)(velocity ft/hr) = discharge ft^3/hr

   Discharge/year = (discharge ft^3/hr)(24 hr/day)(365day/yr)

Part II. Sample to determine load. (Note: This method has some inaccuracy built in, but a more elaborate procedure is impractical.)

A. Materials:

5 one-quart mason jars with caps and seals. (Previously weighed empty, also filled and marked at one-quart level.)

B. Procedure:

Take samples at center of stream in cross-section area without disturbing bottom and cap immediately. (Get exactly one quart.)

C. In Lab:

1. Wt. of container, water, and load - wt. of container = wt. of water and load (use average of five)
2. Weigh filter paper.
3. Agitate sample and pour into filter ⟶ dry solids and weigh.
4. Weight of solids and paper - weight of paper = weight of solids (use average of five)
5. Evaporate remaining water and weigh evaporites. (Use average of five.)
6. Solids + Evaporites + 10% = Load/quart

   ↑

   [10% for traction load dragged or bounced along stream bottom]
7. Load/quart x 4.0 = Load/gallon

   (Load/gal)(7.480 gal/ft^3) = Load/ft^3

   (Discharge ft^3/yr)(load/ft^3) = Load/year

Part III. Can you list at least five reasons why this is inaccurate and how these inaccuracies can be corrected?

LESSON 19

EROSION AND RUNNING WATER

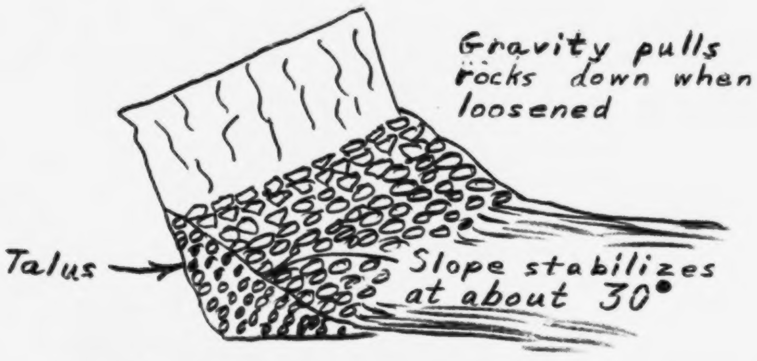
I. Erosion is the process involved in sculpturing the land.

   A. Forces of erosion include streams, glaciers, wind, and waves.

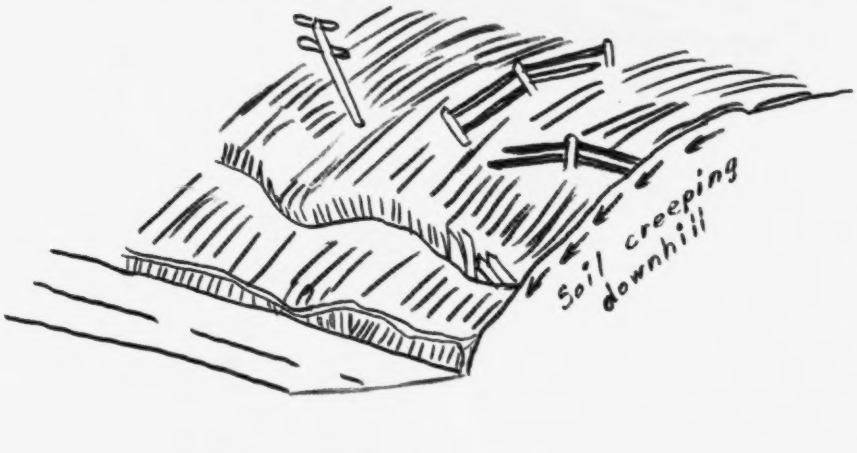
   B. The forces of erosion are constantly at work at all points on the earth's surface above sea level, seeking to reduce these points to base level of the sea.

II. Many factors affect erosion. Among the most important is gravity. Gravity acts continuously, pulling materials downslope. Many movements are a direct result of the action of gravity. Normally these involve large amounts of material and are referred to as mass wasting.

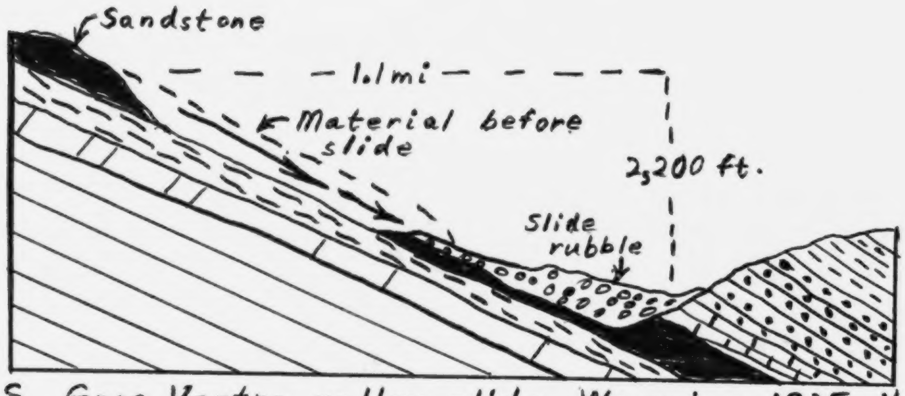
   A. Loose rock falling from cliffs and steep slopes form talus piles at the foot of the slope.


Gravity pulls rocks down when loosened
Talus
Slope stabilizes at about 30°

   B. Soil moving slowly down slope causes retaining walls to collapse and telephone poles to tilt over at odd angles.

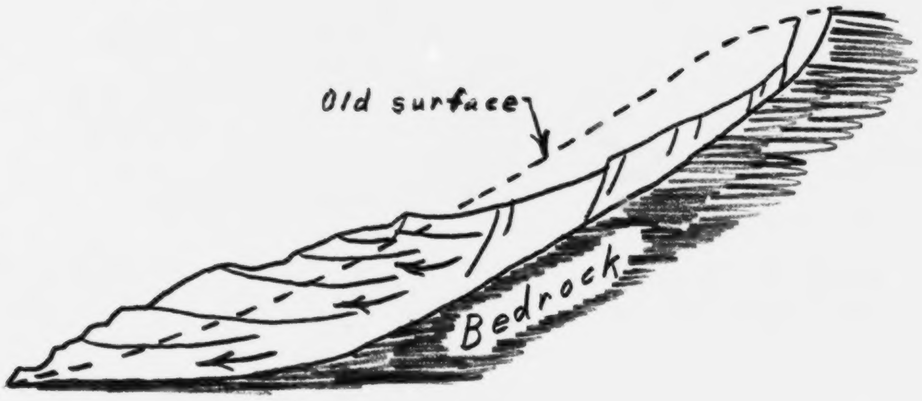

Soil creeping downhill

C. When a slope or cliff is weakened by excessive rainfall or seismic vibrations, great masses of rock may break loose and slide down slope.

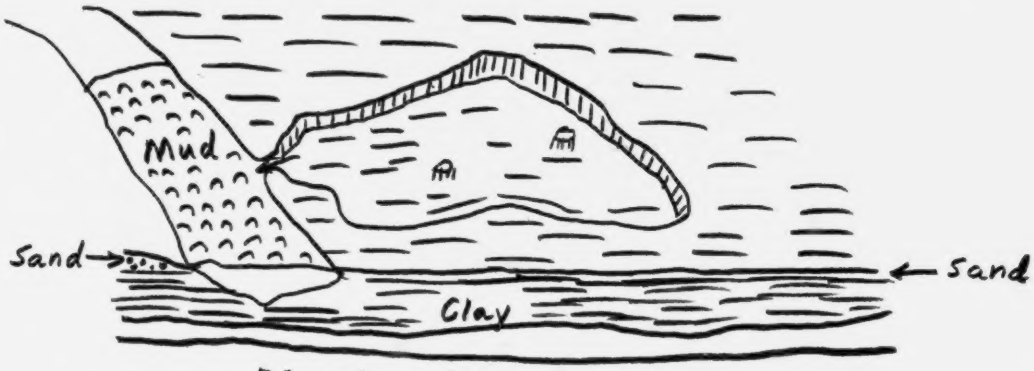

Sandstone
1.1 mi
Material before slide
2,200 ft.
Slide rubble
S
N

S Gros Ventre valley slide, Wyoming 1925 N

D. Often when banks are cut too steeply, soil is unstable; and when there is plenty of rainwater for lubrication, small slumps will occur.


Old surface
Bedrock

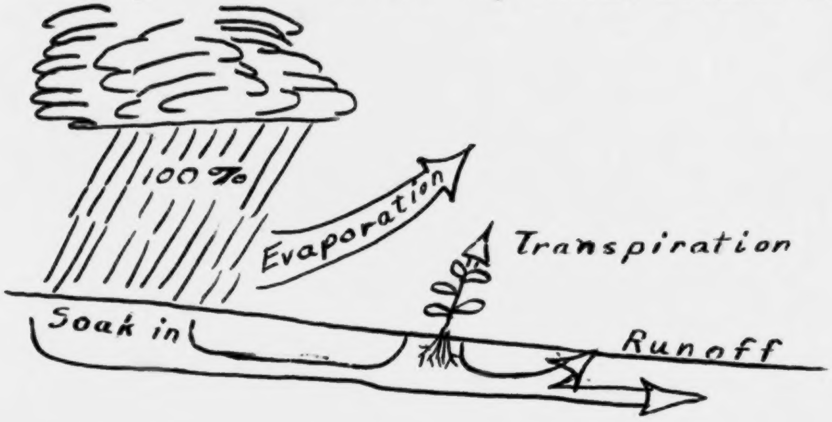
E. With certain types of soil, excessive rain can cause massive mudflows.


Mud
Sand
Sand
Clay

Blanche river, Quebec

III. Next to gravity, the most important force involved in reducing the land surface is running water.

A. The water falling from the clouds may follow several routes.



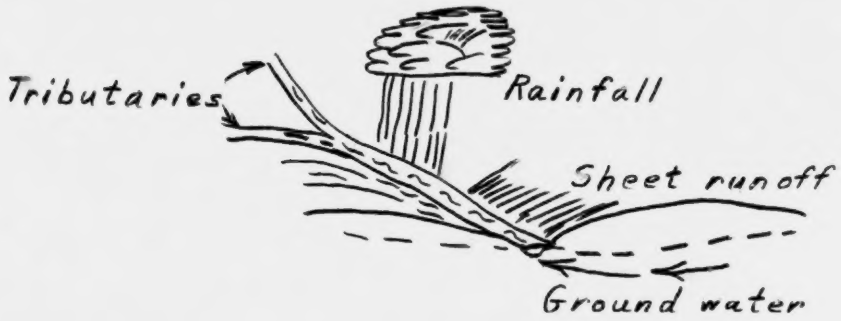
B. The water which stays on the surface begins its trip to the sea as a sheet flowing over the land surface. This is known as sheet runoff and does little eroding.

1. As slopes steepen, small gullies develop which later will become small streams.

2. The steeper the slope, the greater the erosional capacity of the runoff water.

C. The water flowing in streams may come from several sources:

1. Rainfall
2. Sheet runoff
3. Tributary streams
4. Ground water.

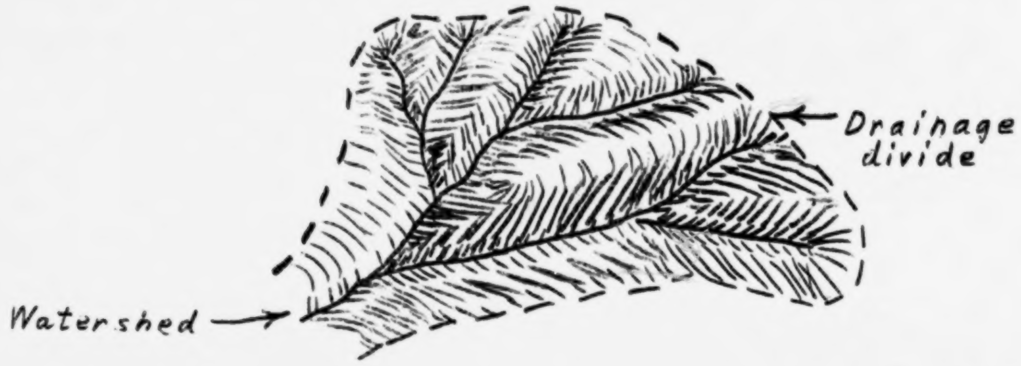


D. The effectiveness of a stream in carrying on erosional work is determined by several factors.

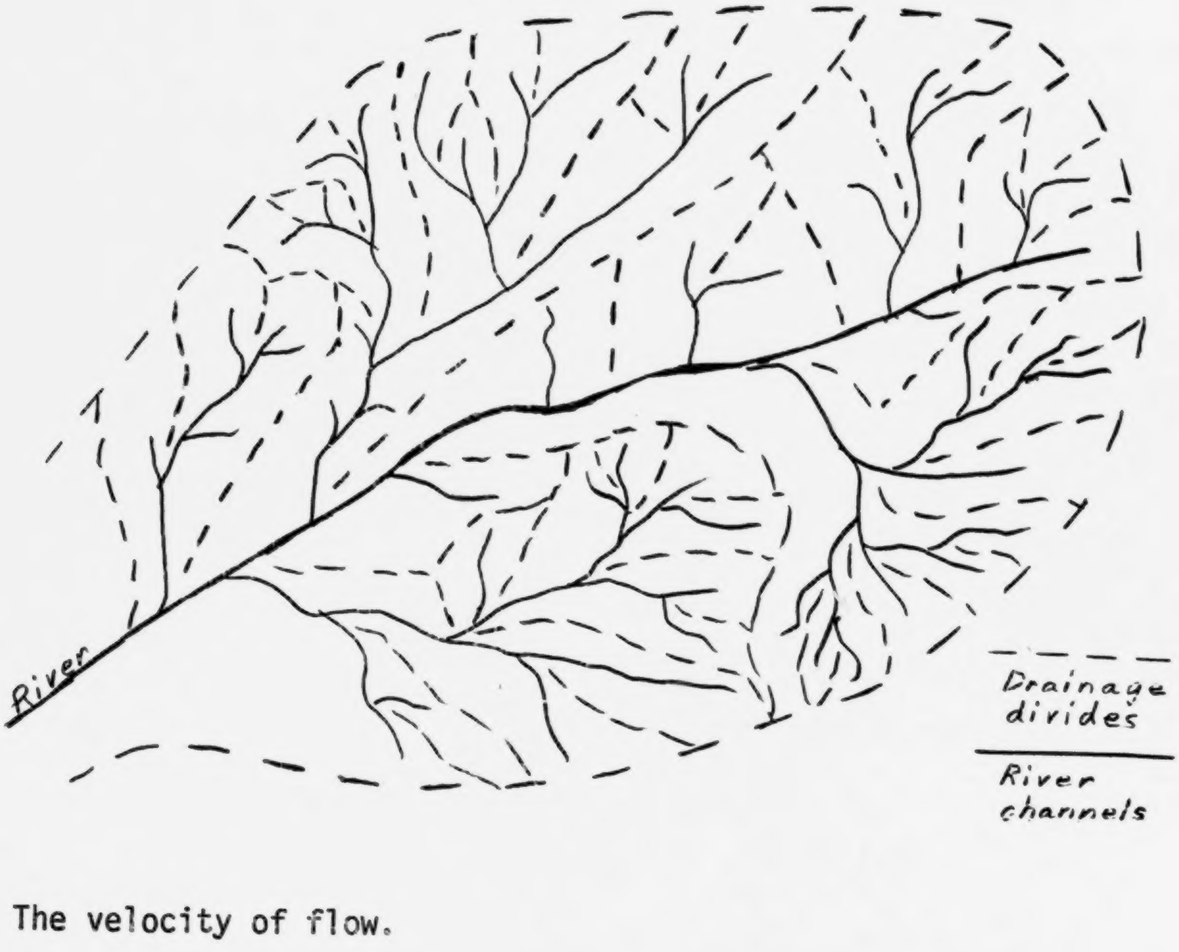
1. The volume of water flowing through the channel in a given period of time is controlled by the watershed area.

a. Watershed area is the area of land from which rainfall will flow into a particular stream.

b. Watersheds are bounded by high land which separates the rainfall into two or more areas. These natural boundaries are known as divides.


Drainage divide
Watershed

c. Watersheds vary in size from individual creek areas to continental drainage basins.


River
Drainage divides
River channels

2. The velocity of flow.

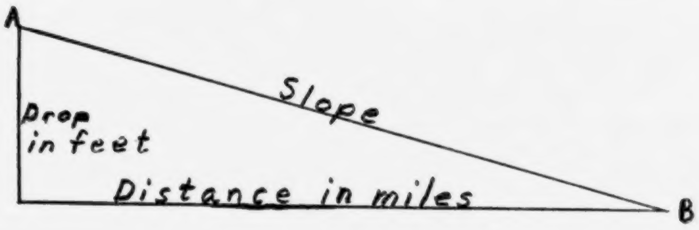
   Velocity depends on the gradient or slope in feet per mile.

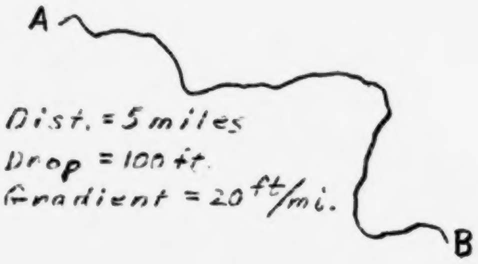
   a. If the gradient is large or steep, the stream has a high velocity.

   b. If the gradient is small or gentle, the stream has a low velocity.

c. Gradient is the slope of the channel:

$$\frac{\text{difference in elevation}}{\text{distance along streams}} = \frac{\text{rise (in feet)}}{\text{run (in miles)}} = \text{gradient ft/mi}$$


A
Slope
Drop in feet
Distance in miles
B


A
Dist. = 5 miles
Drop = 100 ft.
Gradient = 20 ft/mi.
B

3. The type of flow is determined by the gradient.

   a. With low gradients, water follows a laminar flow, or sheet-like pattern, and little erosional work is done.

   b. With high gradients, the flow is rough and irregular, or turbulent, and more erosional work is done.

4. Erosion in a stream can occur in several ways.

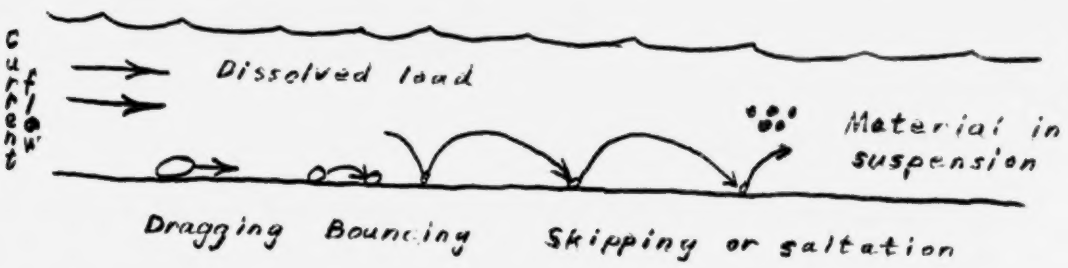
   a. Hydrolic plucking-- Suction of water lifting pieces of the stream bed.

   b. Abrasion-- The grinding of one particle against another resulting in the reduction of the size of both.

   c. Solution-- Dissolving of the stream bed materials in the water flowing by.

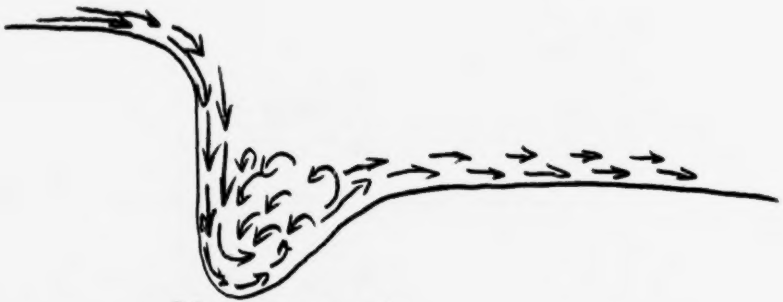
   d. Sliding or rolling of large particles along the bottom of the stream.

   e. Saltation-- Skipping and bouncing of smaller particles.


Current flow
Dissolved load
Material in suspension
Dragging
Bouncing
Skipping or saltation

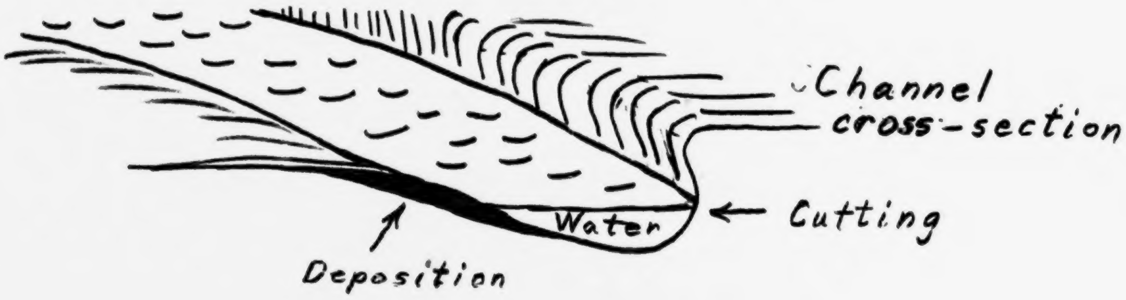
5. Erosional action is most pronounced in turbulent areas.

   a. At the base of waterfalls, turbulence results in increased abrasion and hydrolic action-- often forming plunge pools and undermining the falls.

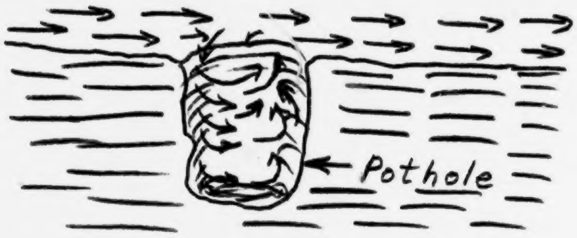


Plunge pool

   b. On the outside edge of turns in a channel, the impact of the water results in excessive erosion and undercutting.



   c. Rocks caught in an eddy, or whirlpool, may grind a pothole in the channel bottom.

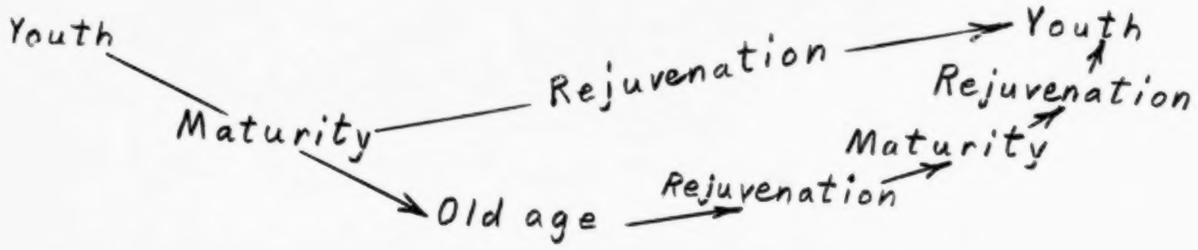


IV. Stream Life Cycles

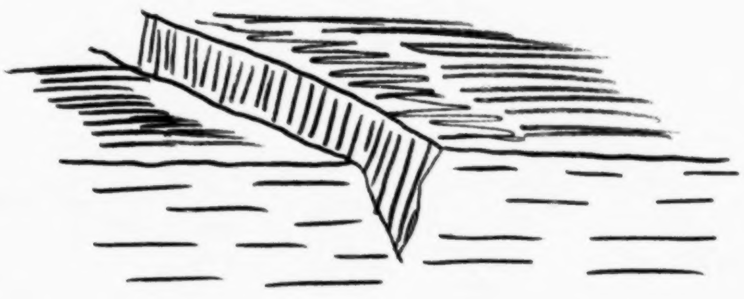
Streams tend to have channel shapes and other characteristics that are typical of a gradient. As the stream erodes its channel, removing material and reducing its gradient, the stream passes through three relatively distinct stages known as youth, maturity, and old age.

These ages are relative only to gradient; and, therefore, a stream may change gradient and age several times over its length. In fact, it is not unusual for a stream to begin as a youthful stream at its headwaters, become mature at a lower gradient, and enter the sea as an old-age stream.

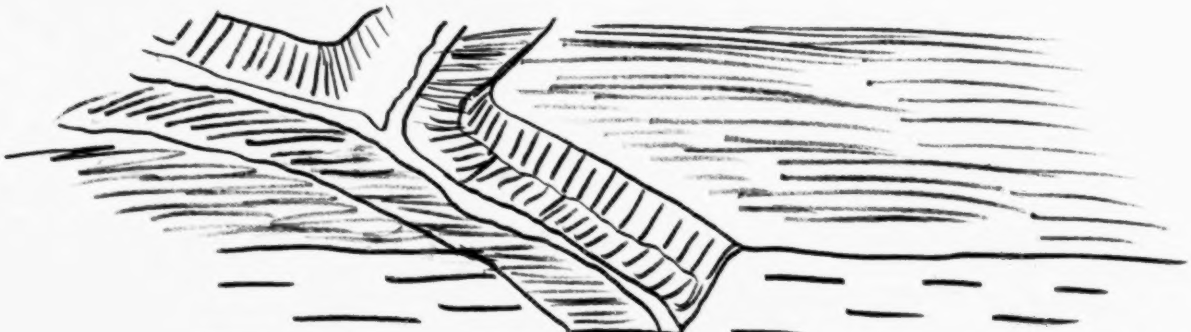
Uplift of the land surface, or a lowering of the sea level, may increase the gradient, thus increasing the rate of erosion and rejuvenating the stream to an earlier age.



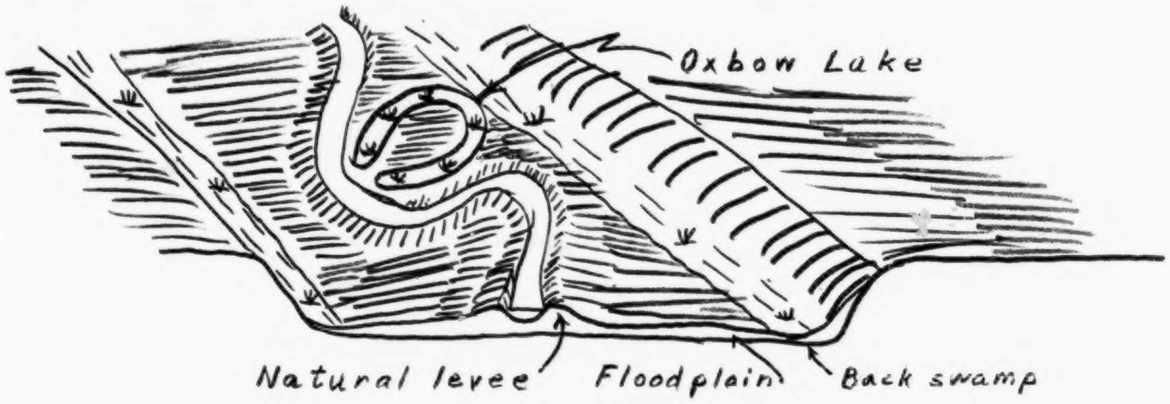
A. Youthful streams-- characteristically have steep gradients. Their valleys are steep-walled and V-shaped with few tributaries. Also, there are usually large numbers of waterfalls and rapids.



B. Mature streams-- show a pattern of well-established tributaries which drain the watershed area efficiently. The gradient of the stream is not nearly as steep, and most of the waterfalls and rapids have been worn away. Because of the gentle slope, the stream channel tends to be deflected and wanders, or meanders.

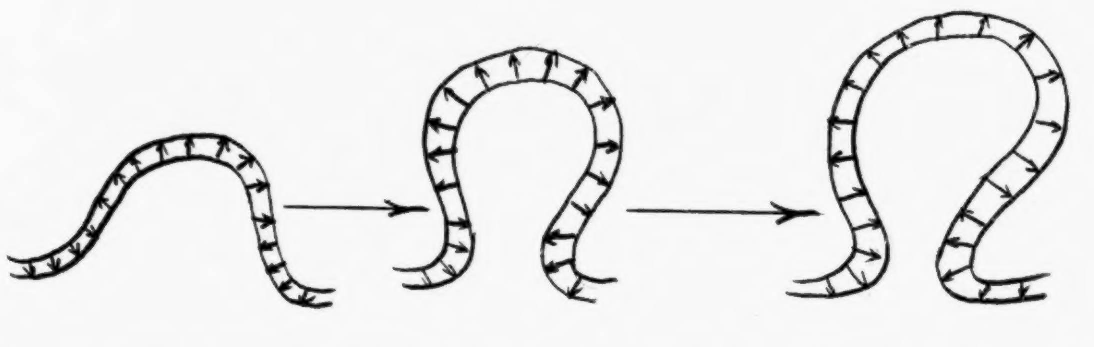


C. Old-age streams-- have extremely low gradients, and, as a result, the flow is quite slow. Normally, the river valley is quite wide, and the river channel meanders extensively across a well-developed flood plain.

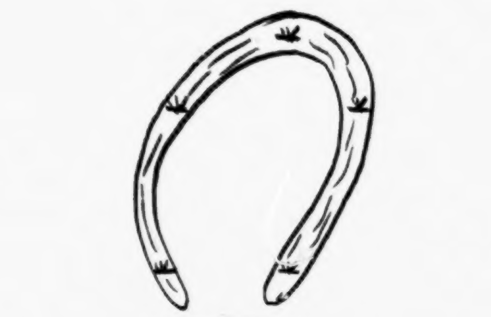


1. The channel of late-mature and old-age streams tend to wander in large loops called meanders.

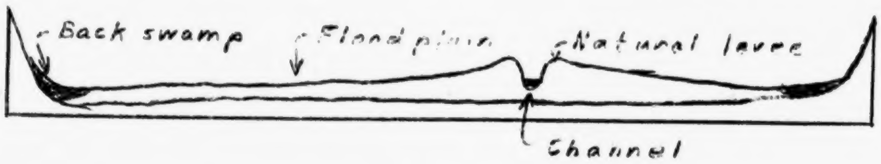
2. Meanders are developed by erosion on the outside of turns in the river or stream channel.



3. As the cutting continues, the meanders tighten until cut-off occurs and an oxbow lake is formed.



4. This process of cutting will widen a stream valley and develop flood plain deposits


Back swamp
Flood plain
Natural levee
Channel

with natural levees and back swamps.

5. Rejuvenation may cause entrenchment of old-age meanders or a mature channel, giving rise to some of the most rugged topography on earth.

LESSON 20, Introduction

RUNNING WATER AND LAND FORMS

Objectives:

1. To develop a concept of the process of deposition.
2. To understand the processes involved and the factors affecting the development of land forms by running water.

References:

1. THE EARTH - SPACE SCIENCES, Chapters 16 and 25.
2. FOCUS ON EARTH SCIENCE, Chapter 13.
3. INVESTIGATING THE EARTH, Chapters 12 and 13.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 13 and 14.
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 24.
Wyckoff. ROCKS, TIME, AND LAND FORMS (Harper and Row, New York), Chapter 4.
Gilluly, et al. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company), Chapter 12.
Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 18 and 19.
Shelton. GEOLOGY ILLUSTRATED (W. H. Freeman & Company, San Francisco),

Activities:

1. Investigating the deposition of sediments
   ESCP Investigation 13-1 — Text 292
   Teacher's Manual 357-359

2. Investigating stream action
   ESCP Investigation 12-7 — Text 280
   Teacher's Manual 341

3. Laboratory: Erosion and Transportation

In this investigation, we shall investigate the relationships involved in erosion and transportation of alluvium by streams.

PROCEDURE: Set up a stream table by smoothing out the sand. Allow the water to run slowly onto the upper part of the stream table. Watch carefully for the development of a channel.

a. Where did the material that was in the channel go? ____________

____

b. After a channel has developed, experiment with the speed of the water by varying the flow from the hose. What general relationship can you find between flow and rate of erosion? ____________

____

c. Place several small pebbles in your stream channel. Gradually increase the speed of flow. What relationship do you notice about flow and size of particles that can be carried by the stream? ____

____

d. Without changing the flow of water, increase the gradient of your stream by raising the back. What relationship can be found between the erosion done by the stream and the gradient of the stream? ____

____

e. Form in the stream channel a series of bends (meanders). Allow water to flow down this curved channel. Where is erosion taking place in the meander curves? Why? ____________

____

4. Laboratory: Deposition

In this laboratory, we shall investigate relationships involving deposition of alluvium by streams using a stream table. Deposition takes place where the stream loses part of its load-carrying capacity. We shall investigate several conditions where deposition occurs.

DELTAS:

Load-carrying capacity of a stream is reduced when the velocity of the stream is reduced. Velocity decreases when a stream enters a standing body of water such as a lake or ocean. Reduction in velocity causes deposition of the transported material on the floor of the basin. This type of deposit is called a delta.

Raise the rear section of the stream table and form the sand in a gentle slope toward the shoreline. Form a stream valley down the center of the table. Let the water flow at a moderate rate. Watch the development of your delta.

What general shape does your delta take? Why? ______________________

____

ALLUVIAL FANS:

If the gradient of a stream changes suddenly, the reduction of velocity causes the deposition of part of the transported material on the flat land surface. This type of deposit is called an alluvial fan.

Raise the rear section of the table and form the sand as a gently sloping upper section with a drop near the center of the table to an almost flat plain at the foot of the drop. The plain should slope very slightly toward the basin. Shape a stream channel in the center of the table. Allow a slow to moderate flow of water down the channel. Watch the development of your alluvial fan at the foot of your cliff.

How is the alluvial fan like the delta? ______________________

____

How is the alluvial fan unlike the delta? ______________________

____

BRAIDED STREAM:

A sudden decrease in velocity will allow the stream to drop part of its load in and along the stream bed. If the load is deposited in the channel, the stream becomes braided.

Form several bends (meanders) in the stream channel. Allow the velocity of the stream to increase slowly until you can see particles rolling along the bed. Then, suddenly decrease the volume.

What happened to the particles that were being carried by the stream at the higher velocity? ______________________________

____

MEANDERS:

Increase the volume until you can just see movement of the water. Observe the meander bends in your channel.

Describe the flow of the stream around the meanders. ____________

____

Where does the deposition take place in the meander curves? ________

____

FLOOD PLAIN DEPOSITION:

Increase the volume until the lower areas adjacent to the stream are flooded. Watch the material being carried by the streams.

What happens to part of a stream's load during flooding? __________

____

This area of deposition is called a flood plain. Where are the heavier particles in the stream load deposited? ______________

____

This type of deposit is called a natural levee.

Observe the movement of the water across the meander necks during the flooding.

What is happening as the water crosses the necks of the meanders? ____

____

This process aids in the formation of oxbow lakes.

Observe carefully the processes acting on the meander loops. Vary the speed of water flow to aid your observations. Experiment carefully and observe the changes that take place in the meanders.

Describe the shifting of meander loops in rivers and streams. You may use a diagram.

5. Laboratory: Stream Gradient

From the data below (taken from the Renova West Quadrangle, Pennsylvania) construct a profile of Kettle Creek and the Susquehanna River from B.M. 1118 to Renova. Using the long edge of the graph for distance and the shorter edge as elevation, plot and label each point given in the table and complete the graph by connecting your points with a line. This is the profile of the stream. For your horizontal scale (distance from Renova), let each large vertical line represent a distance of 5 miles. Number each line accordingly. For your vertical scale (elevation), let each large horizontal line represent an increase of 100 feet. Number each line accordingly. Make sure your graph is labeled neatly and correctly. Neatness is essential in graphing.

POINT	DISTANCE FROM RENOVA (MILES)	HEIGHT ABOVE SEA LEVEL (FEET)
Renova	0	640
Shintown	2.3	660
Mouth of Kettle Creek	5.3	675
Westport	6.1	680
Two-Mile Branch	7.1	700
Short Bend Run	8.5	720
B.M. 750	9.5	950
Between Five-Mile Hollow and Owl Hollow	11.0	760
Summerson Run	12.0	780
Honey Run	13.4	800
Butler Hollow	14.8	820
Summerson Bridge	16.0	925
Leidy	17.6	860
Hammersley Fork	18.9	885
Hevner Run Bridge	21.4	925
Turtle Point Hollow	23.6	960
Hogstock Run	25.9	1000
Laurel Hill Bridge	27.9	1030
Cross Fork	28.4	1040
B.M. 1073	30.0	1073
B.M. 1118	31.0	1118

ANSWER THE FOLLOWING QUESTIONS: (Show your work)

a. Find the gradients between:

(1) B.M. 1073 and B.M. 1118.

Answer: ____________ ft/mile

(2) Westport and Two-Mile Branch.

Answer: ______________ ft/mile

(3) What is the average gradient per mile between the two end points of your profile?

Answer: ______________ ft/mile

b. In what part of the stream is the gradient lowest? ______________

____

c. In what part of the stream is the gradient steepest? ____________

____

d. How do you account for the differences in gradient along the stream?

____

____

____

____

LESSON 20

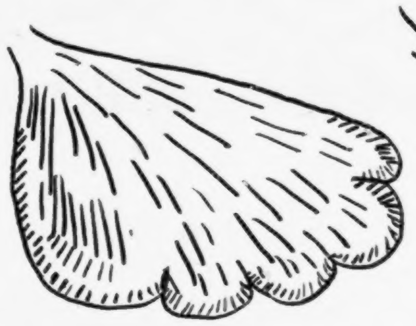
RUNNING WATER AND LAND FORMS

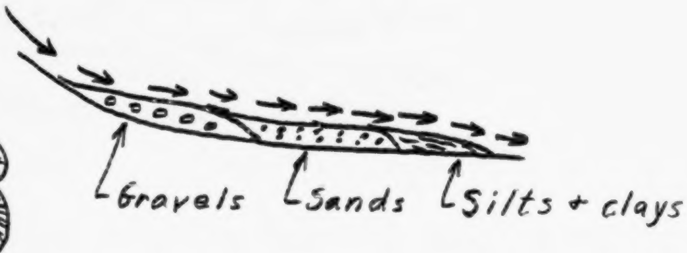
I. Deposition by Streams.

The amount of material that a stream can carry is called its load. A stream's load is determined by: the velocity (the faster a stream flows, the more it can carry); the volume (the larger a stream's volume, the more load it can carry); and the material available for transport.

A. As a stream slows down, the load it is carrying must decrease; therefore, some is dropped to the channel bottom.

1. Stream flow may slow down because of a sudden decrease in gradient. Normally such a decrease will result in the formation of an alluvial fan.



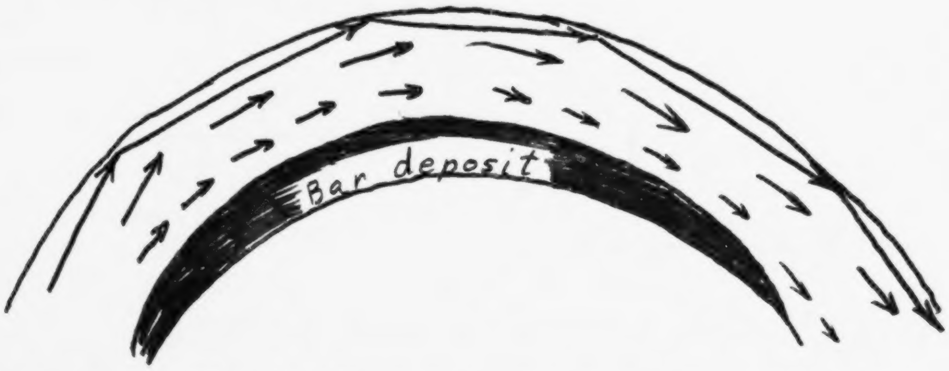


2. Stream flow slows abruptly when the stream enters a body of water such as a lake or sea. The deposition of material under these conditions usually results in the formation of a delta except when currents along open coasts sweep the material away.

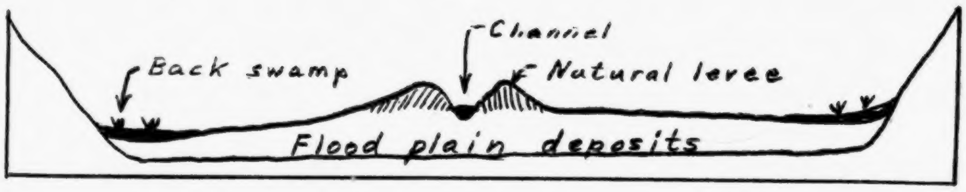
    a. When the stream slows down, progressively finer material is dropped.

    b. The resulting sorting locates shorelines, gives the history of deposition, and often yields information on climate.

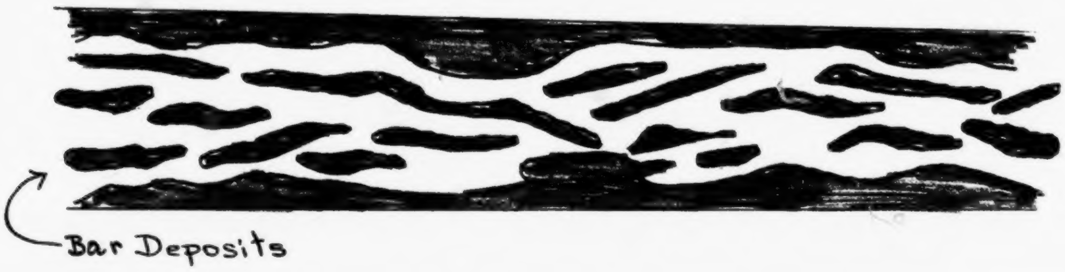
3. Deposition occurs on the inside of meander loops in the stream channel forming a bar.



4. Overflow during floods along mature and old-age streams results in flood plain deposits and natural levees because of material dropping near the stream edge as the water slows down.

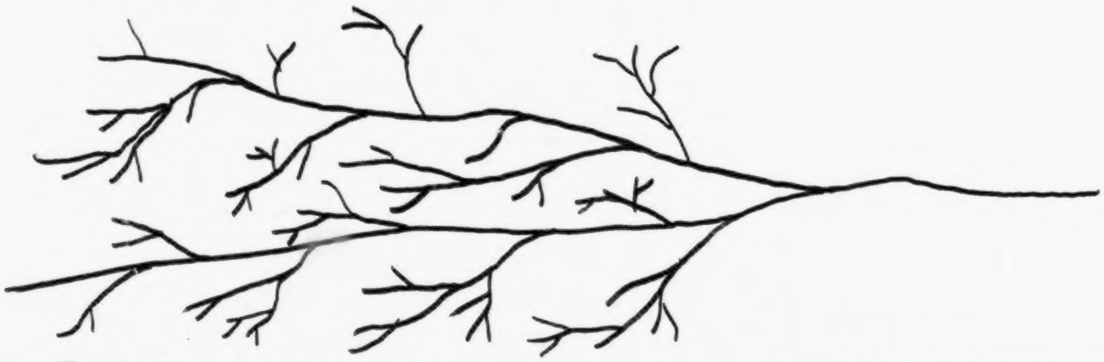

Channel
Back swamp
Natural levee
Flood plain deposits

5. A decrease in volume because of a drought or an increase in load can cause a channel to become braided or divided into many small clogged channels.

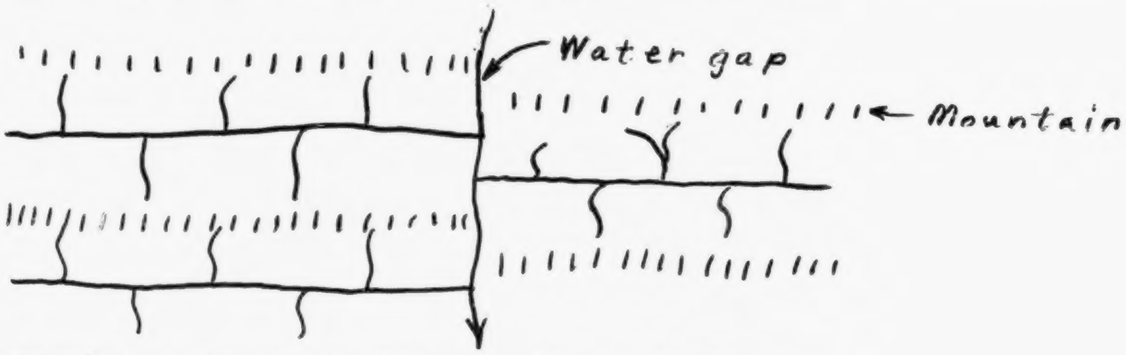

Bar Deposits

II. Streams take drainage patterns caused by the rocks over which they flow.

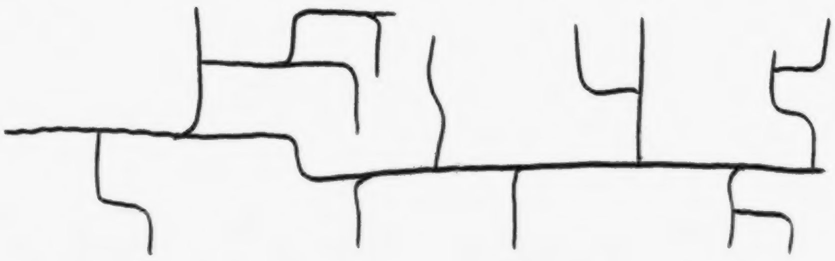
A. Dendritic Stream (tree like) - flows over rock of equal resistance to erosion.



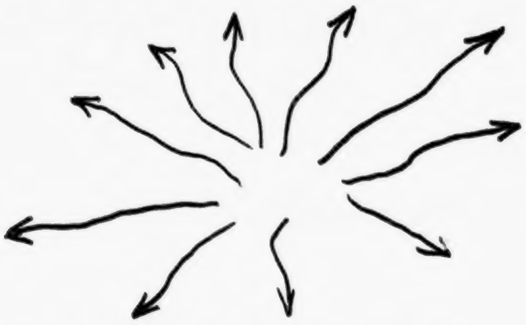
B. Trellis - determined by rocks of unequal resistances to erosion. (Example: upturned strata in the Appalachians.)


Water gap
Mountain

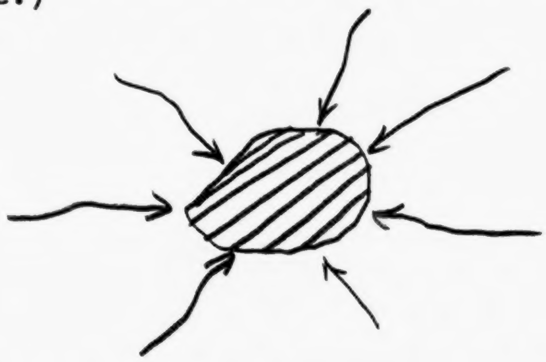
C. Rectangular - due to faulting and/or jointing.



D. Radial - flow out from a common center. (Examples: Dome Mountains, Crater Lake.)



E. Centripetal - flow into an interior basin. (Examples: Basin and Range Province.)



III. Other Important Terms to Mention (time permitting).

A. Consequent stream - pattern determined by the slope of the land.

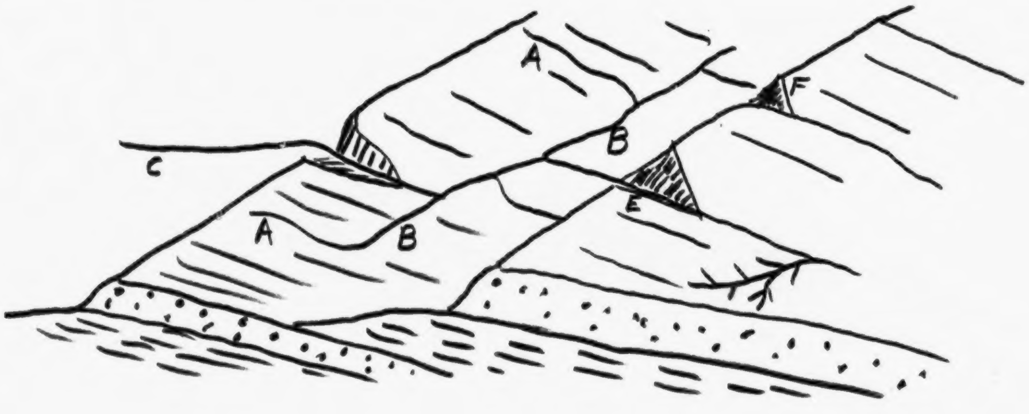
B. Subsequent stream - pattern determined by belts of weak rock such as folded strata.

C. Antecedent stream - maintained its course across a local uplift of the crust that rose by folding or faulting in its path.

D. Superposed stream - let down from overlying strata onto a buried surface below.

E. Water gaps - may be cut by antecedent and superposed streams.

F. Wind gaps - abandoned water gaps.



IV. Sculpture of the Land by Streams

A. A peneplain is the result of stream cutting, weathering and erosion, etc.

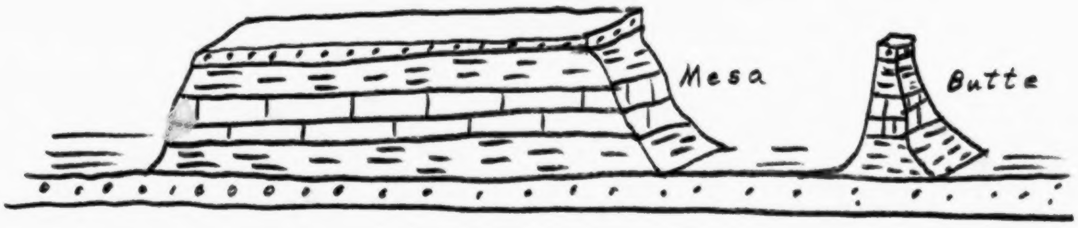
1. Peneplain means "almost a plain."

2. Peneplain surfaces are created near sea level as erosion wears away the land.

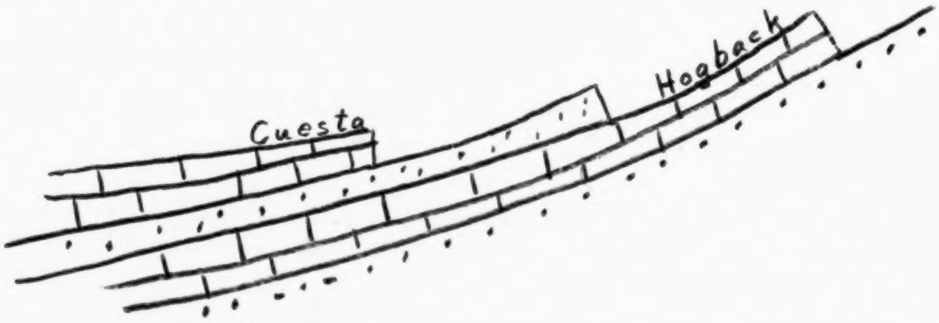
3. The North Carolina Piedmont is an example of a dissected peneplain. (Peneplain has been uplifted and is now cut by stream erosion.)

B. Special land forms result when the rock hardnesses are not the same and erosion takes place more rapidly in the less resistant rock.

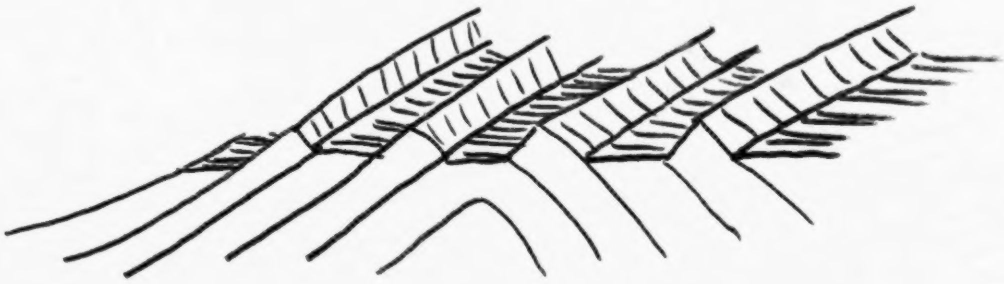
1. Mesas and buttes occur when a more resistant layer acts as protection for the softer lower layers.



2. Cuestas and hogbacks form where more resistant strata are tilted by diastrophism. These often border dome mountains.



3. Ridge and valley topography occur where rock layers of varying resistances have been folded. (Example: Newer Appalachians.)



4. Monadnock - an area that has withstood weathering and erosion because of superior resistance. (Examples: Pilot Mountain, Hanging Rock, Kings Mountain, Mount Mitchell, Grandfather Mountain.)

LESSON 21, Introduction

GROUND WATER

Objectives:

1. To understand the processes by which water moves through the ground.
2. To understand the land forms developed by ground water in terms of process of development, surface features, and life history.

References:

1. FOCUS ON EARTH SCIENCE, Chapter 14.
2. INVESTIGATING THE EARTH, Chapter 9.

Special References:
Wolfe, *et al*. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 15.
Strahler. PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 21.
Gilluly, *et al*. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapter 14.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 15.
Wyckoff. ROCKS, TIME AND LANDFORMS (Harper & Row Publishers, Inc., New York), Chapter 12.
Folsom. EXPLORING AMERICAN CAVES: THEIR HISTORY, GEOLOGY, LORE AND LOCATION (Collier Books, Inc., New York).

Activities:

1. Investigating the Movement of Water in Earth

ESCP 9-3	Text 209 Teacher's Manual 258-261

2. Investigating Water Budgets

ESCP 9-9	Text 218 Teacher's Manual 267-274

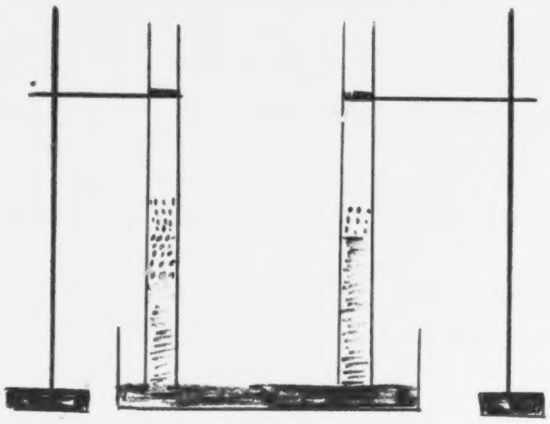
3. Ground water moves downward through pore spaces of rock and soil. Capillary action causes upward movement.

Materials:

2 ringstands with clamps
glass tubes
aquarium
fine sand

Procedure:

Fill two glass tubes (approximately 1 inch in diameter and 1 foot long) about half full of dry, fine sand. Support the tubes vertically with clamps so their bottoms are in some type of flat dish or aquarium. Pour water in one tube. The water will infiltrate down through the pore spaces of the sand, move into the dish, and partially move up the other tube by capillary action.



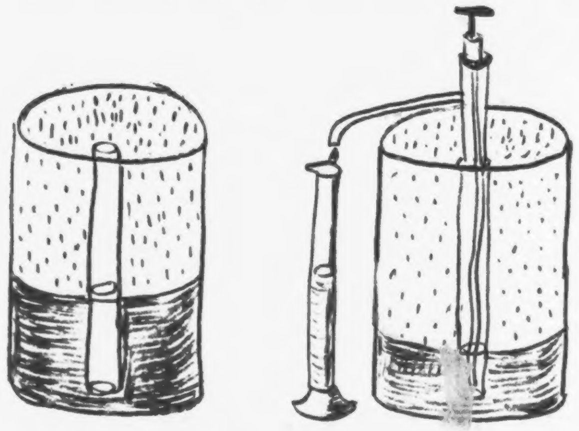
4. Water is stored between grains in rocks where rocks are fractured. The upper limit of this storage is called the water table.

Materials:

sand
large bore glass
battery jar
strip of paper
demonstration lift pump

Procedure:

Hold a large bore glass tube against the inside of a battery jar to represent a well. Fill the jar with sand and pour water on the sand until the water level rises about half way in the jar. Note that the water level is the same outside the well as it is in the well. Rest a narrow strip of wet paper on the jar to mark the water level and develop the term water table. Use a demonstration lift pump to remove some of the water from the well and call attention to the lowering of the water table.



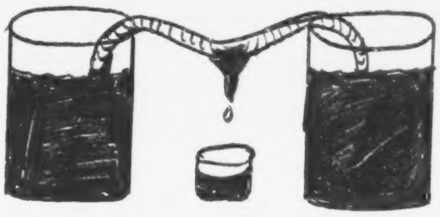
5. The action of ground water in limestone caverns results in a variety of geologic features.

   Materials:

   cord
   2 beakers
   saturated solution of epsom salt

   Procedure:

   The formation of miniature stalactites and stalagmites can be demonstrated by laying a cord between two small vessels filled with a saturated solution of epsom salt as shown in the diagram. In caves, the material deposited is calcium carbonate ($CaCO_3$), dissolved out by ground water.



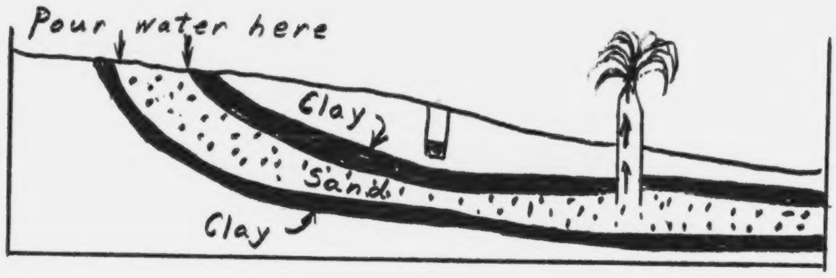
6. Man is able to get water from the ground by penetrating the zone of water saturation.

   Materials:

   large aquarium tank
   modeling clay
   gravel or small pebbles

   Procedure:

   To demonstrate the operation of a well, spring and artesian well, build a water-tight layer of modeling clay at one end of a large aquarium tank to represent an impervious rock layer. Add a layer of gravel or pebbles to act as a water-holding bed. Over these two layers place another layer of modeling clay to represent the upper layer of impervious rock. Then add a thick layer of soil. Explain that the permeable layer is open at the top of the hill. Drill a hole, in the flat area of the soil, with a pencil and insert a medicine dropper stem. Pour in water to represent rain on the hill top; note that water will trickle through the soil to the top layer of clay. Dig a shallow well in the upper soil layer and note that ground water is present. The water trapped between the two impervious layers will squirt out of the medicine dropper to represent an artesian well. To show a spring, drill a hole in the side of the hill and observe the water flow. (For a repeat demonstration remove excess water from above the soil layer by siphon.)


Pour water here
Clay
Sand
Clay

LESSON 21

GROUND WATER

I. Water which soaks into the ground (meteoric water); water buried and trapped in sediments (connate water); and water given off by cooling magmas (magmatic water) all go together to form the ground water supply.

   A. The amount of water that soaks into the ground is determined by a soil's permeability. Permeability (the rate at which water passes through a porous material) is determined by the porosity or amount of space between the grains in a rock.

   B. Porosity depends on:

      1. The sorting or uniformity of the particles in a mass.

      2. Packing - the arrangement of particles in a mass.

      3. Grain shape - rounded or irregular.

      4. Extent of cementation.

   C. Permeability varies:

      1. Loose mantle material is normally very permeable.

      2. Granular rocks are normally more permeable than shale or limestone.

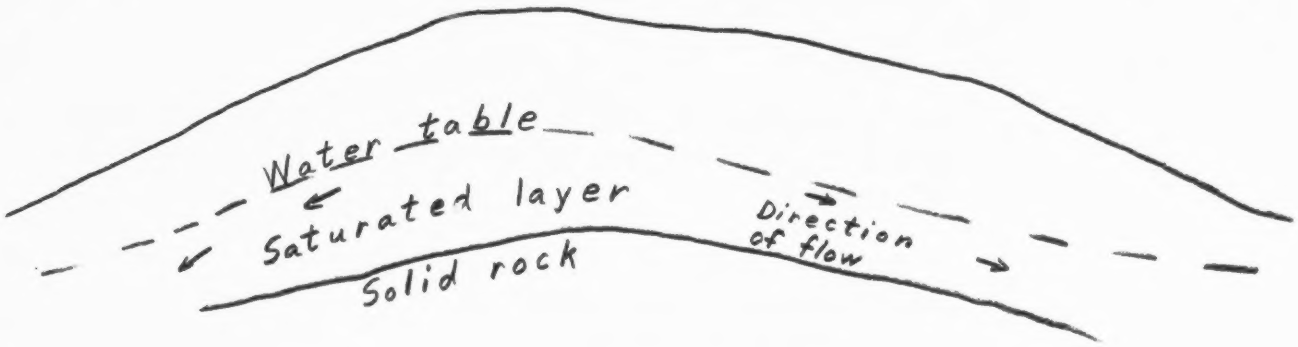
      3. Dense rocks (igneous or metamorphic) are permeable only if there are fractures or joints in the rock.

II. Ground water normally continues to sink until it strikes a completely solid or impermeable layer.

   A. The soil above this layer becomes completely saturated.

   B. The upper layer of the saturated zone is the water table.

   C. Water may flow within the permeable layers thus entering the earth in one place and emerging in another.



D. The rate (speed) at which water moves through the ground depends on two factors.

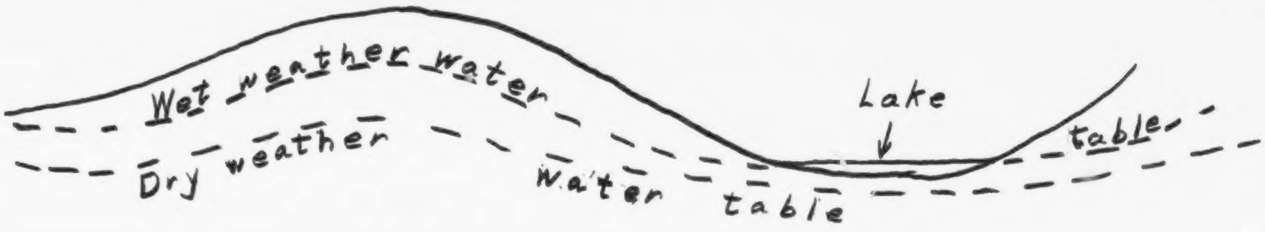
   1. The gradient or slope.

   2. The permeability of the rock. (With very permeable rock and steep gradient, water may move as much as several feet per day.)

E. The level of the water table varies according to the amount of rainfall.

   1. In wet weather the water table rises almost to the surface and conforms closely to the irregular surface of the ground.

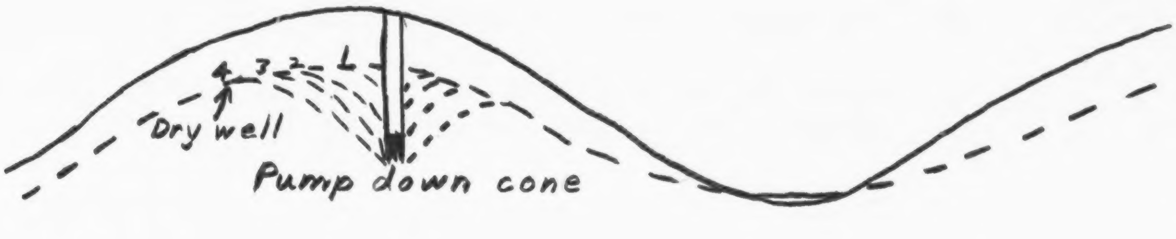
   2. During dry periods, the water table will sink and become almost level.



   3. Wells are holes dug or drilled below the water table.

      a. Any well drilled in permeable rock will usually provide abundant water.

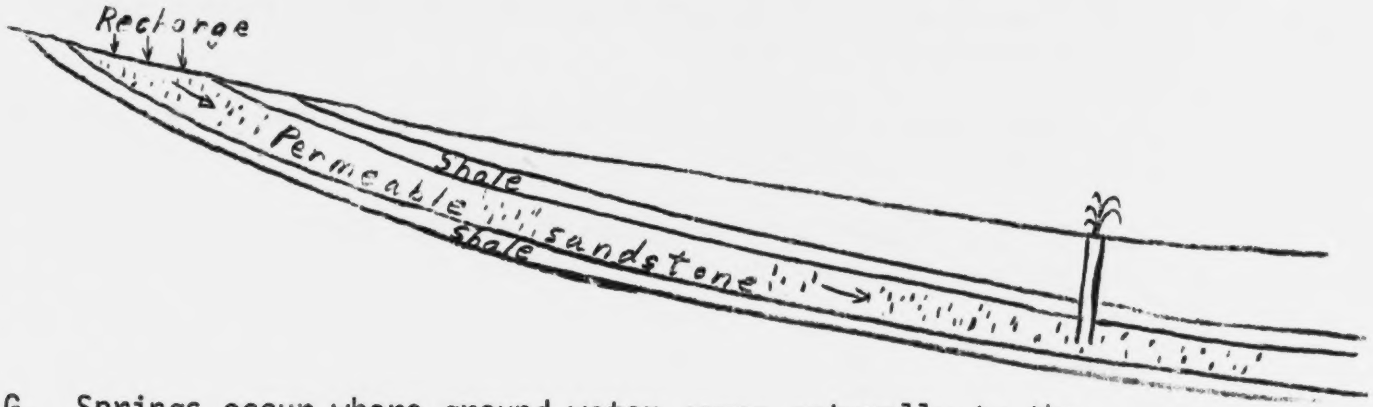
         1) Shallow wells may dry up during dry seasons.
         2) They may also be pumped dry.



      b. Wells drilled in igneous or metamorphic rock will yield little water unless the rock is thoroughly fractured.

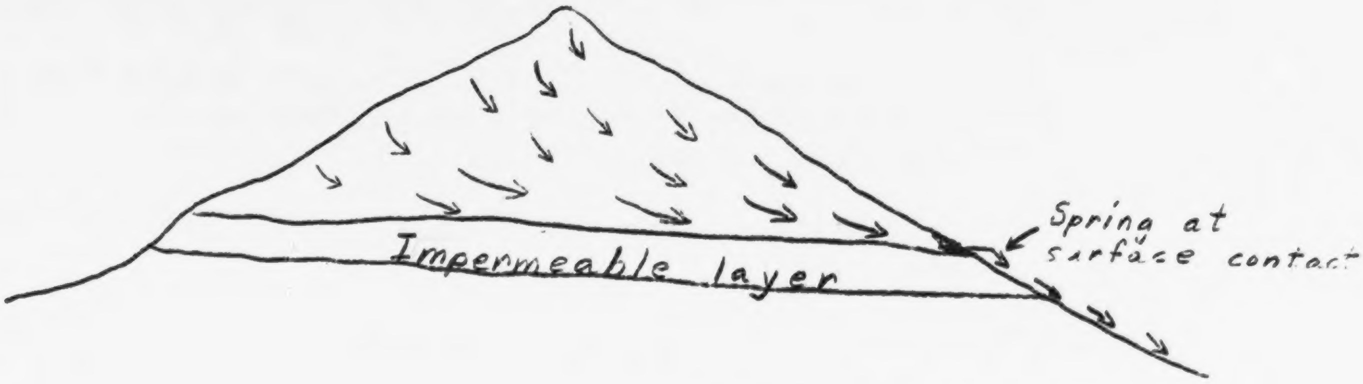
      c. Generally deep drilling is not helpful in impervious rocks because the number of fractures and cracks decreases with depth.

F. Artesian wells are an exception to the general rule in that impermeable rock is necessary for an artesian system to exist.


Recharge
Shale
Permeable sandstone
Shale

G. Springs occur where ground water comes naturally to the surface.

1. Artesian springs.
2. Contact springs.


Impermeable layer
Spring at surface contact

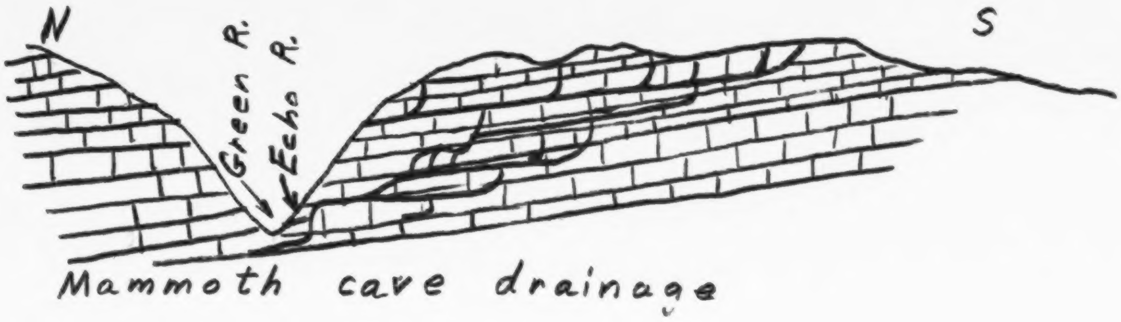
H. Hot springs and geysers are caused by subsurface volcanic activity.

1. Mud springs (Paint Pots) - Boiling evaporates water leaving mud composed of mineral matter.
2. Hot springs yield hot mineral rich water. (Travertine terraces)
3. Geysers form when steam collected in a pocket within the earth throws water and steam up into the air.

III. When rain water with carbon dioxide in solution seeps into limestone beds a chemical reaction occurs which results in the solution of the limestone. This solution and removal of limestone results in the formation of caverns.

   A. Most cavern systems exist below the water table and are therefore not accessable.

   B. If the water table drops draining the caverns and surface access exists, man may enter and explore the cavern.

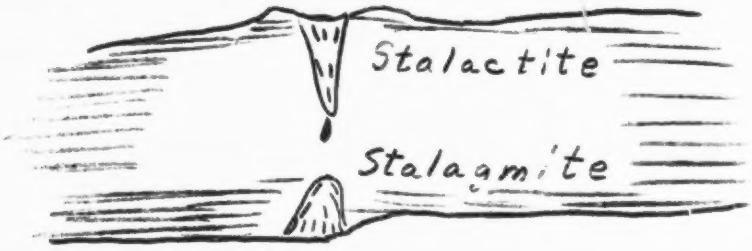


Mammoth cave drainage

   C. Water seeping through a drained cavern can cause the building of:

      1. Stalactites - an icicle-like structure hanging from a cavern ceiling formed when water dropping from the ceiling evaporates slightly leaving a calcite deposit.

      2. Stalagmites - water deposits growing up from the floor of the cavern.



   D. When caverns develop beneath a land surface, they may result in a unique land surface called karst topography.

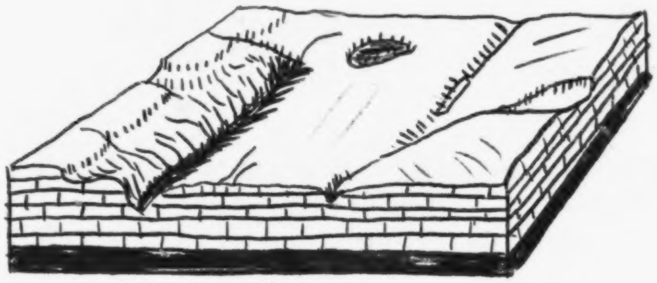
      1. Karst topography is characterized by:

         a. Sinkholes - formed when a cavern roof is weakened and collapses.

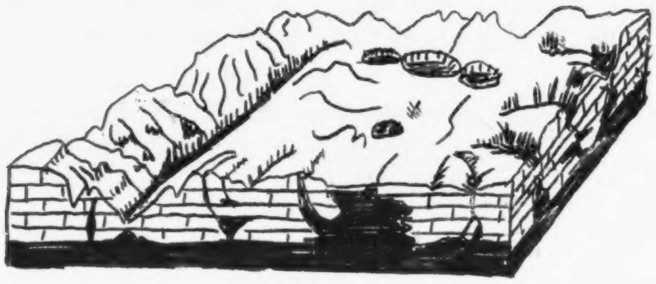
         b. Disappearing streams - flowing into a cavern.

         c. Natural bridges - remnants of a cavern roof.

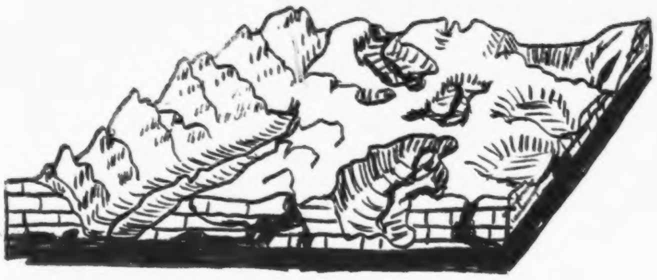
      2. As time passes and solution proceeds, the terrain changes.



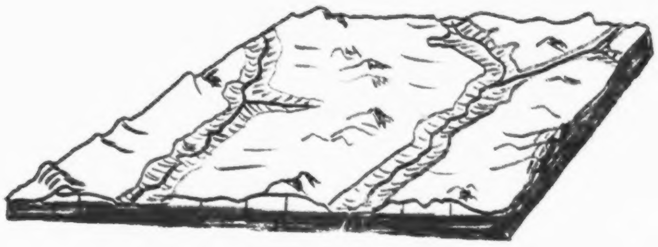
Youth



Late youth



Maturity



Old age

3. Small cavities in limestone may, under certain conditions, be filled by crystals growing out from the walls into the cavity. Such round groups of crystals are known as geodes and are valued as collectors items.

E. In North Carolina massive limestone formations occur across the coastal plain; however, the only known caverns occur at Linville in a portion of the shady dolomite formation.

IV. While most of the material taken into solution by ground water makes its way eventually to the sea; some is left behind when water evaporates from the soil.

   A. When excesses of salts and calcium carbonate are concentrated at the surface, a crust or caliche may form. This type of hardpan surface can be found in many deserts.

   B. Often the movement of ground water will transport and concentrate material in layers below ground or in lumpy forms called concretions.

LESSON 22, Introduction

EROSION BY ICE AND WIND

Objectives:

1. To develop a concept of the effects of ice and wind as erosional agents.
2. To understand the processes employed by ice and wind in erosion, transportation, and deposition of material.
3. To gain a knowledge of glacial and wind-caused land forms.

References:

1. FOCUS ON EARTH SCIENCE, Chapters 15 and 16.
2. INVESTIGATING THE EARTH, Chapter 12.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 16 and 18.
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 28 and 26.
Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapters 13 and 15.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 20 and 22.

Activities:

1. Wind is a destructional force helping to create the landscape.

Materials:

electric fan
sand
large box

Procedure:

On a windy day observe what the wind does to leaves, twigs, and other debris on the ground. Look in corners protected from the wind and notice that soil, leaves, and other materials are sometimes deposited there.

Pour a pile of dry sand or granulated soap on the bottom of a large carton cut away on one side. Turn an electric fan on the pile of sand and notice how the particles are moved. Notice that more particles are moved as the velocity of the wind increases.

Put an obstacle such as a pencil or finger in the path of the blowing sand and observe what happens. Relate this to the principle of snow fences and the behavior of sand dunes.

2. Ice can be plastic, depending upon the speed with which pressure is applied.

   Materials:

   aluminum foil
   a freezer
   water

   Procedure:

   Freeze an elongated bar of ice approximately 19 x 2 x 1 inches. (Aluminum foil may be used to make a tray of the proper size.) Remove the ice from the tray and, while keeping it at freezing temperature in the freezer, suspend it at both ends. Place a weight in the middle of the bar. After a few hours, the bar of ice will be bent and will not spring back to its original shape after the weight is removed.

3. The melting point of ice is lower when under pressure.

   Materials:

   freezer
   wire
   weight

   Procedure:

   Suspend a bar of ice at both ends in a refrigerator or deep freezer where the temperature is at or slightly below freezing. Loop a wire around the bar, and suspend a weight from the wire. The wire will be seen to eat its way down through the block. The water produced by melting under the pressure of the wire will refreeze in the crack above the wire where the pressure is less.

4. Ice flows plastically near the bottom of a glacier. The upper part of a glacier is brittle.

   Materials:

   ice
   hammer
   silly putty

   Procedure:

   Demostrate the brittleness of ice when not under pressure by breaking ice cubes with a hammer. Demonstrate the plastic flow of ice by placing some silly putty on a sloping surface and observe it flow under its own weight.

LESSON 22

EROSION BY ICE AND WIND

I. Introduction

In areas of colder climate, ice may accumulate to such a depth that it begins to behave as a plastic and flow. Such a unit of flowing ice is called a glacier.

A. Valley glaciers (alpine glaciers) occupy valleys previously made by streams.

B. Piedmont glaciers are glaciers located on a plain at the base of a mountain range and fed by one or more valley glaciers.

C. Continental ice sheets are broad glaciers of irregular shape generally blanketing the terrain.

D. Glaciers (all types) cover about 6 million square miles of the earth's surface. (about 10-11% of the earth).

II. Glaciers advance away from a source area or zone of accumulation.

A. The two chief requirements for glacial formation are:

1. Low temperature

2. Adequate snowfall (more falls than melts)

B. Glaciers are found in high latitudes and high altitudes and are more numerous along wet coastal areas.

C. Zones of accumulation are normally found above the snow line. The snow line is the elevation above which the air temperature seldom rises above freezing and snow tends to accumulate rather than melt.

III. Snow accumulates as the source of nourishment for a glacier.

Most glaciers can be divided into two zones.

A. Zone of accumulation.

1. Snow accumulates, but air spaces in crystals allow evaporation, forming water vapor.

2. Snow becomes granular (as does all old snow).

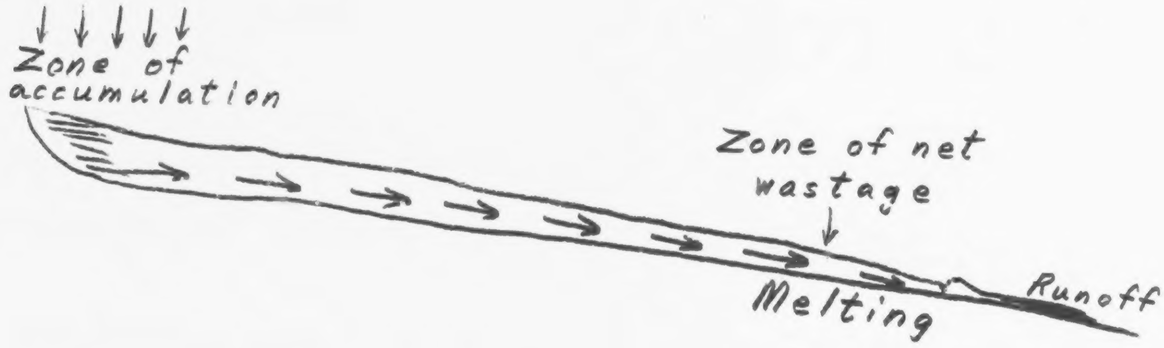
3. Compression due to the weight of overlying snow causes ice to form.

B. Zone of net wastage.

1. Area in which melting is greater than accumulation.

2. Meltwater results from the melting of glacial ice.

3. Glacial deposition occurs in this area.



IV. Ice is a weak solid. Its own weight is enough to overcome rigidity so that it becomes deformed, flowing downward and outward as a stiff liquid. (Example: putty or clay)

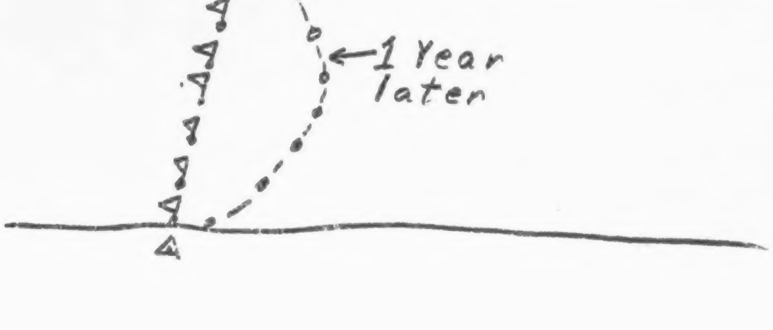
A. Observing change of position on a glacier was the earliest method of detecting movement.

B. Surveying a line of stakes across the glacier can detect the movement of a glacier.

1. Sides and bottom of the glacier are thought to be held back by friction.

2. The center of the glacier is found to move fastest.

3. Crevasses form in the brittle upper surface of the glacier as it moves.



V. A glacier transports material known as its load.

  A. The load of a glacier may be carried on top, in its sides, and within the body of the glacier.

  B. Much larger particles can be carried by a glacier than by streams or wind.

  C. The load is concentrated in the base and sides of the glacier.

VI. A glacier carries on erosion by abrasion and plucking and is generally accompanied by weathering in the form of frost wedging.

  A. Frost wedging cracks, splits, and prepares rocks for glacial transportation.

  B. Glacial plucking is the lifting out and removal of pieces of bedrock by a glacier.

    1. Pieces are quarried out, especially on the downstream side of the glacier.

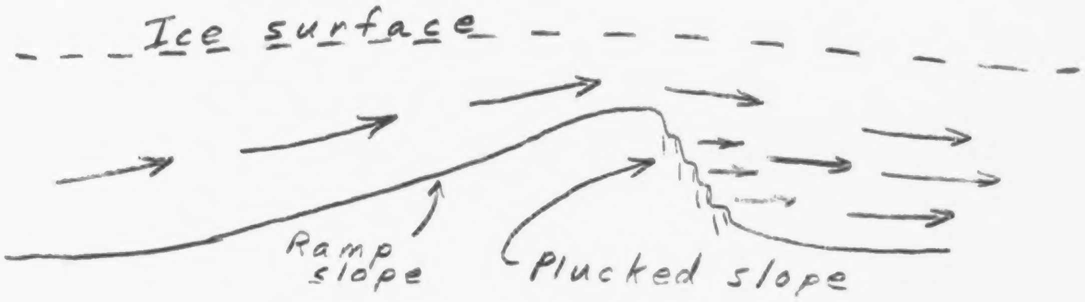
    2. Water aids plucking by freezing and lifting.

  C. Abrasion is a filing process.

    1. Ice makes scratches and grooves called glacial striations.

    2. These striations and the asymmetrical shape of rock hills point the direction of the movement.

      a) Upstream side - abraided, striated, gently sloping.
      b) Downstream side - predominantly plucked, steeper slope.

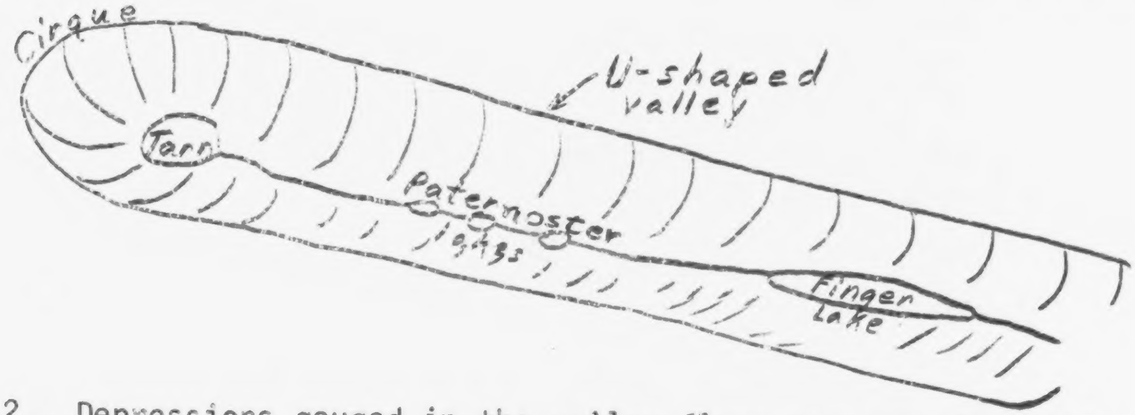


VII. The eroding action of glaciers, particularly valley glaciers, creates unique features which identify previously glaciated mountain ranges.

  A. Cirques - steep-walled, bowl-shaped depressions at the head of glacial valleys. Formed by plucking at the head of the glacier.

B. U-Shaped valleys - caused by erosion of both the sides and base of alpine (valley) glaciers.

1. The head of the valley is usually marked by a cirque often with a small lake located in the depression called a tarn.

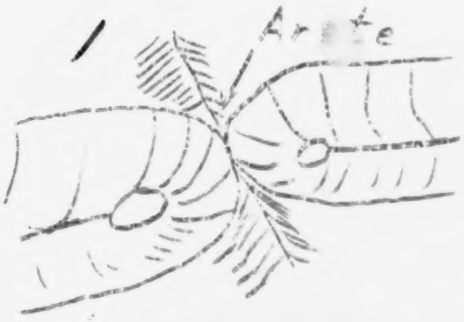


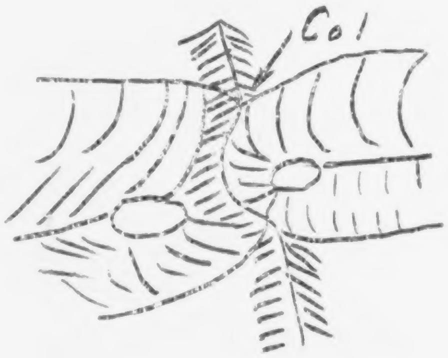
2. Depressions gouged in the valley floor may contain small elongated (finger) lakes or chains of small round lakes (paternoster lakes).

3. When the old glacial valleys are flooded, they are known as fiords.

NOTE: Continental glaciers generally do not cut U-shaped valleys since they are quite deep and cover both mountains and valleys.

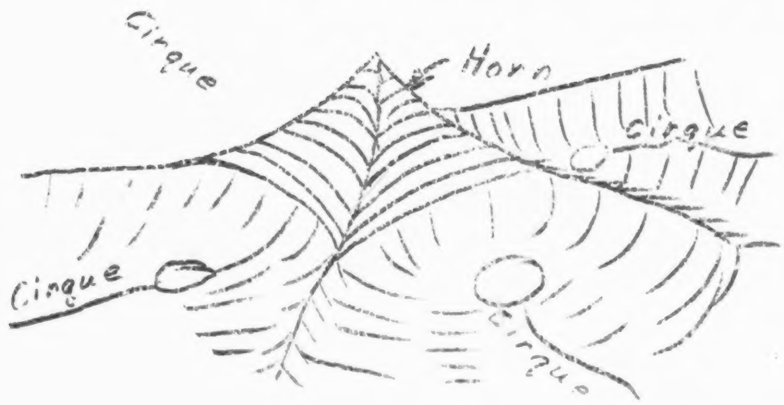
C. Arete - a jagged, knife-edge ridge created by two cirques that have eaten into the ridge from both sides.





D. Col - a knife-edged, saddle ridge formed when the same type of glacial erosions that formed an arete continued eroding both sides of a ridge.

E. Horn - usually a bare, pyramid-shaped peak left standing where three or more cirques intersect from different directions.

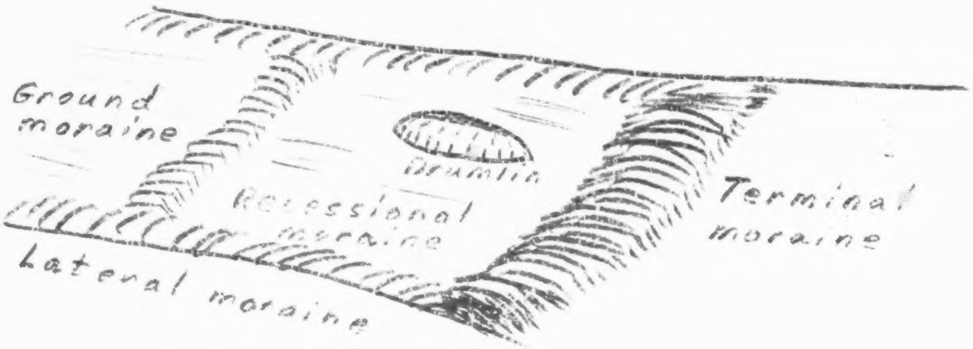

Cirque
Horn
Cirque
Cirque
Cirque

VIII. Glacial deposition takes place mainly in the downstream portion of a glacier where melting releases rock fragments from the ice.

A. Till - (non-sorted) material not sorted according to size and weight but lying just as it was released from the ice. The term "till" includes all unsorted glacial deposits.

B. Moraines are landforms concentrated by a glacier from a till. There are several types of moraines.

1. Ground moraine - Widespread thin till with a generally smooth surface and irregularities resulting from irregular distribution of rock particles in the glacier. Form as the glacier retreats (melts back).
2. Terminal moraine - Ridge-like accumulation built at the end of a glacier as the glacier remains stationary losing the debris it carries.
3. Recessional moraine - Glacier pauses during retreat forming a series of ridges.
4. Lateral moraine - Ridge built along the edge of the glacier.
5. Medial moraine - Blending of lateral moraines of two valley glaciers in a piedmont glacier or in a larger valley glacier.


Ground moraine
Drumlin
Recessional moraine
Terminal moraine
Lateral moraine

6. Drumlins - Streamlined hills molded by flowing ice; offers minimal frictional resistance to the ice flowing over them. (Indicates direction of flow of former glaciation.)

7. Erratics - Glacially deposited pieces of rock that are different from the bedrock beneath them.

IX. Meltwaters from glaciers also erode, transport, and deposit materials. These materials tend to be sorted and stratified, but their origins are usually clearly glacial. The materials can be separated into two categories.

A. Outwash deposits.

1. Outwash plains are formed by water flowing away from melting glaciers. They typically are broad, flat, and found in a portion of the valley or region formerly occupied by the glacier or just beyond the terminal moraine.

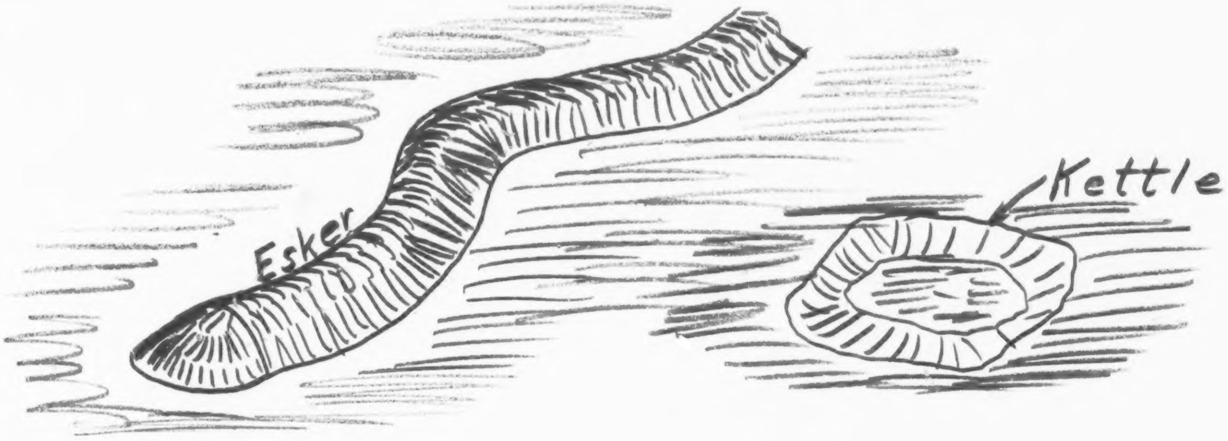
2. Valley trains are stratified deposits partially filling a valley.

B. Ice-contact stratified drift landforms are developed by running water in contact with ice.

1. Kames - low, conical, steep-sided hills formed by water pouring over the edge of a glacier. The internal structure is normally stratified with some slumping which occurred when the ice melted.

2. Eskers - usually narrow, steep-sided serpentine ridges of gravel and sand with an internal slumped stratified structure. They are believed to represent channels of streams which flowed on top of or within the melting glacier.

3. Kettles - depressions in the ground moraine caused by the melting of buried chunks of glacial ice.



X. Wind is the least effective of all the erosional agents; however, it still does considerable work in terms of shaping the land.

  A. Wind is more effective in areas that are arid.

  B. Wind is particularly effective in deserts and along sea shores.

  C. Wind is also effective in flat areas and in areas of glacial deposition.

  D. Many plains and plateaus fit into the categories listed above and are especially affected by wind erosion.

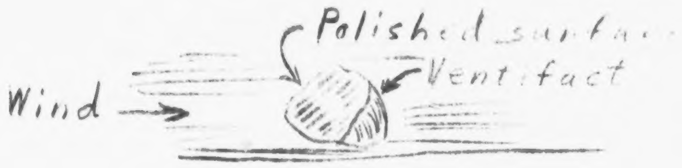
XI. Wind erodes the land surface in at least two ways.

  A. Deflation - picking up and removing loose particles by the wind.

    1. This process removes the smaller particles and leaves the larger ones as a surface covering called "desert pavement."

    2. The wind also excavates hollows or depressions by deflation.

  B. Abrasion (grinding) by particles carried by the wind produces ventifacts which are polished and faceted fragments of rock.



XII. Winds build deposits on deserts, plains, and beaches.

  A. Dunes are constructed when wind slows down, dropping material. The size of the particles and the amount of material the wind can carry depends on the wind velocity.

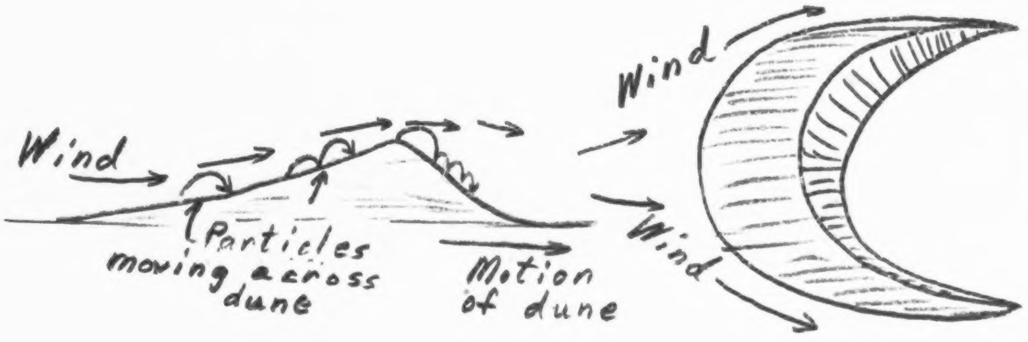
    1. Dunes are hills of wind-blown sand.

      a. Started by an obstruction.

      b. The more gentle slope on the windward side is caused by the flattening action of the wind.

      c. Barchanes are crescent-shaped dunes formed when wind blows around edges of the dune.

2. Dunes migrate downwind as particles are blown across the dune.


Wind
Particles moving across dune
Motion of dune
Wind
Wind

B. Loess is a deposit of silt-sized particles.

1. There are thick deposits in Kansas.
2. Loess is composed of very fertile soil, but is weak and susceptible to erosion.

LESSON 23, Introduction

DEPOSITION AND SEDIMENTARY ROCK

Objectives:

1. To develop a concept of the processes involved in the formation of sedimentary rock.
2. To understand that environmental conditions may determine the type of rock formed and, in turn, indicate part of the history of an area.

References:

1. THE EARTH-SPACE SCIENCES, Chapters 23 and 25.
2. FOCUS ON EARTH SCIENCE, Chapter 6.
3. INVESTIGATING THE EARTH, Chapters 2, 18 and 19.

Special References:

Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 9.

Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapter 17.

Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 6 and 7.

Activities:

1. The making of a fossil.

   Materials: shells, bones, plaster of Paris, containers, modeling clay

   Procedure:

   Place a layer of clay in the bottom of a small container. Press the bones or shells into the clay. Lift the bones or shells out carefully so that a clear imprint remains. Mix plaster of Paris and fill the cavity in the clay. After the plaster has set, remove the cast from the mold.

   How does the clay compare with settling sediment? How does the plaster of Paris compare with minerals deposited in ground water?

2. Investigating an ancient stream channel.
   ESCP 18-4
   Text 396
   Teacher's Manual 492 and 495

3. Investigating the puzzle.
   ESCP 18-6
   Text 399
   Teacher's Manual 495 and 497

4. Investigating areas of erosion and deposition.
   ESCP 21-2 Text 457
   Teacher's Manual 581-582

5. Investigating the leveling process.
   ESCP 21-3 Text 488
   Teacher's Manual 582-584

LESSON 23

DEPOSITION AND SEDIMENTARY ROCK

I. Introduction

The material eroded, transported, and deposited by gravity, water, wind, and ice is transformed into sedimentary rock by the processes of compaction and cementation. Sedimentary rocks are divided into two groups which are based in part on their origin.

A. Fragmental sedimentaries are made up of fragments of other rocks that have been carried by water, wind, or ice and deposited, compressed and cemented to form rock.

1. These types of rocks are generally grouped according to the size of fragments they contain.

a. Conglomerates are coarse-grained and formed from fragments varying in size from boulders to small particles. The particles may come from one or several types of rock.

(Boulders over 265 mm or 10 inches)
(Cobbles 64-264 mm or 2.5-10 inches)
(Gravel 2-64 mm or 0.8-2.5 inches)

b. Sandstones are formed from cemented sand grains.

(Sand .2-2 mm or .008-.08 inches)

c. Siltstones are formed from silt grains.

(Silt .02-.2 mm or .0068-.008 inches)

d. Shales are formed mainly by compaction from clay particles and tend to be flatly cleaved into plates.

(Clay less than .02 mm or .0008 inches)

B. Chemical sedimentaries are formed from materials precipitated from solution in water.

1. Fragmental limestones may be fragmented and/or precipitated. The particles may vary from fairly large to microscopic shells, and they usually are cemented by precipitated limestone.

2. Limestone ($CaCO_3$) may be precipitated from chemical solutions because of evaporation or a change in temperature or salinity.

3. Dolomite (dolomitic limestone $CaMg(CO_3)_2$) is precipitated when calcium magnesium carbonate is present.

II. Compaction and Cementation.

A. Before loose sediments can be cemented effectively, they usually must be compacted to some degree. This is usually accomplished by the weight of overlying sediments being deposited on an existing layer. The increasing weight forces water and air out and moves the particles closer together.

B. Deposits sometimes do not form sedimentary rocks because they are only deposited for a short time, to be picked up again and carried on to a new site by running water.

C. Compacted sediments are slowly cemented into rock by small amounts of substance usually dissolved from the sediments themselves.

1. The principal cementing materials include:

a. Silicon dioxide (quartz).

b. Calcium carbonate (limestone).

c. Ferric oxide (rust).

2. The resistance of the various cementing agents to weathering varies considerably. Thus the character of the weathering is, in part, dependent on the cementing material in a particular rock.

III. Limestone is by far the most common sedimentary rock. Therefore, the character and formation of limestone is of some interest.

A. The same water that carries solid fragments may also carry dissolved carbonates.

1. Calcium carbonate is the most important of the carbonates.

2. Calcium carbonate is insoluble in pure water.

3. Calcium carbonate dissolves easily in water containing CO_2.

4. The solubility of $CaCO_3$ is also affected by temperature and other conditions.

5. Thus, precipitation may occur in certain areas where conditions are right.

B. The most common source of $CaCO_3$ is the skeletons of plants and animals that live in the sea.

1. Generation after generation vast numbers of skeletons settle to the bottom of the sea.

2. The skeletons are compacted into deposits of limestone.

3. Coral is also responsible for large deposits of limestone.

C. Varieties of limestone.

1. Most limestone is dense or very fine grained and either white, light, or dark grey in color.

2. Chalk is a variety of limestone composed of microscopic shells.

3. Shell limestone - Shell fragments cemented together or having shell imprints.

4. Coquina - Composed of recent shells or shell fragments loosely cemented.

5. Travertine - Cave deposits.

6. Flint nodules are also found in limestones. These are siliceous concretions within the limestone.

IV. Character and information from sedimentary rocks.

A. The classification of sedimentary rocks is based on texture, mineral composition, and origin.

1. Texture provides distinction between conglomerate, sandstone, and shale and siltstone.

2. Chemical composition (minerals) provides distinction between limestone and other sedimentary rocks. (Limestone will effervesce in HCl.)

3. Origin is also very helpful in sedimentary identification.

B. The character and structure of a sedimentary rock may yield much information about the conditions in the area under which it was formed.

1. Certain types of rock are formed only under certain conditions. Example:

a. Coral reefs form only in tropical and semi-tropical waters.

b. Sandstone is usually deposited in a transitional environment.

c. Conglomerates are formed by water moving rapidly when that water is slowed down.

2. The thickness of sedimentary layers (beds) tells something about the time required for their deposition.

3. The fossils present give information concerning environment, age, conditions in the area, etc.

    a. Fossils are found only in sedimentary or very slightly metamorphosed rock.

        1) Fossils are the remains of ancient life.
        2) The chances of preserving an organism as a fossil are exceedingly remote.

            a) The organism must be buried at the time of death or within a few days after death.
            b) Normally only the hard parts of an organism are preserved.

    b. Fossils are often helpful in determining both geologic age and changes of environment.

        1) Index fossils - Often found in rock layers of one geologic time only. The position of a formation may be established with respect to time.
        2) Environmental fossils - Indicate the environmental conditions of a certain age. (Example: marine vs. fresh water)

C. There are three major types of fossilization.

1. Essentially unaltered remains:

    a. Entire remains preserved (exceedingly rare).

        1) Frozen mammoths and other mammals.
        2) Amber sometimes preserves insects intact.

    b. Hard parts only preserved (usually recent).

        1) Bones of mammals have been found.
        2) Some dinosaur bones. (Dinosaur National Monument)

2. Altered remains.

    a. Carbonized - Plant remains changed during coal formation.

    b. Replacement due to ground water. Original cells replaced by minerals out of solution in ground water.

        1) Calcified ($CaCO_3$)
        2) Silicified (Silica).
        3) Pyritized (Pyrite).

Process often referred to as permineralization. (petrification).

3. Indirect evidence of presence of life is often preserved.

    a. Casts and molds

    b. Trails, tracks, and burrows.

    c. Fossil excrement.

    d. Artifacts are important in the study of early man.

    e. The study of fossil evidence is a subbranch of the science of Geology known as Paleontology.

D. The order in which rocks are formed and their arrangement fall into the realm of structural geology and stratigraphy. This information tells much about the order and sequence of events.

LESSON 24, Introduction

DIASTROPHISM

Objectives:

1. To understand the process of diastrophism.
2. To develop concepts of isostasy and plastic deformation.
3. To create an image of the landforms developed by diastrophic movement--particularly folding and faulting.

References:

1. THE EARTH-SPACE SCIENCES, Chapters 23 and 25.
2. FOCUS ON EARTH SCIENCE, Chapters 17 and 18.
3. INVESTIGATING THE EARTH, Chapters 14, 16, and 18.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 11 and 12.
Wyckoff, ROCK, TIME, AND LANDFORMS (Harper & Row Publishers, Inc., New York), Chapter 5.
Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company), Chapters 6, 8, 9, 10, 19 and 20.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 2, 3, 9, 26 and 27.
Shelton, John S., GEOLOGY ILLUSTRATED (W. H. Freeman and Company, San Francisco).
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 29 and 30.

Activities:

1. Development of an idea-James Hall's Field Trip.
   ESCP 14-1 Text 312
   Teacher's Manual 379-383

2. Developing a folded surface.

   Materials:

   Different colors of clay and a cutting wire.

   Procedure:

   Roll (flatten) several layers of clay and put them together. Fold the layers by pressing from the edges. Using the wire cut the sandwich as water would erode the surface. Repeat the process eroding horizontal structures as well as plunging anticlines and synclines.

3. Investigating regional landscapes.
   ESCP 21-7 Text 467
   Teacher's Manual 590-595

LABORATORY ACTIVITY

DIASTROPHIC STRUCTURES

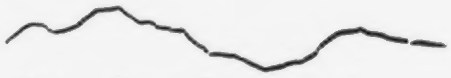
Each block in this series is a square slice of the earth's structure. Therefore each block contains evidence of various kinds which reveal the history of that part of the earth's surface. Completing the diagrams will help you understand how the geologist reads the record of the earth's history, both in the field and from geologic maps constructed by other geologists.

The following symbols will be used throughout the entire activity to represent various types of rocks and structural features.

STRUCTURAL SYMBOLS:

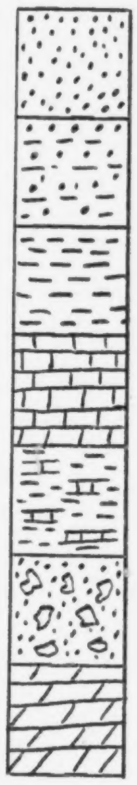
Conformal contact between beds

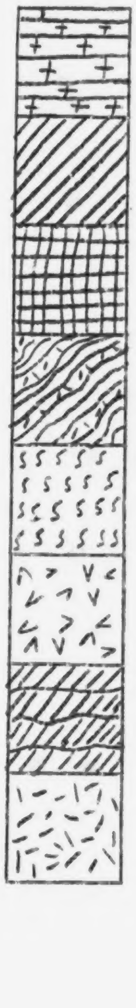
Fault line



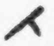
Unconformal contact

ROCK SYMBOLS:

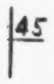

Sandstone
Sandy Shale
Shale
Limestone
Limey Shale
Conglomerate
Dolomite


Marble
Gypsum
Salt
Gneiss
Schist
Granite (or granitic intrusive)
Basaltic Lava Flows
Basaltic (mafic) Intrusive

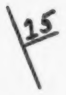
STRIKE AND DIP SYMBOLS:

To indicate strike and dip a small symbol () is made on a geologic map. The long line shows the direction of strike and is made on the geologic map in the compass direction of the strike. The short line shows the dip direction and is always at right angles to the strike. A number indicates the angle of dip.

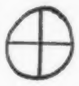
EXAMPLES: (North is to the top of the page.)



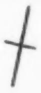
Strike: N - S
Dip: 45°E



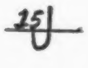
Strike: N25°W
Dip: 15°NE



Horizontal Beds



Vertical Beds Strike: N15°E
Dip: 90°



Overturned Beds Strike: N90°W
Dip: 15°N

BLOCK 1

1. Complete the block by putting in all the necessary symbols.
2. What is the strike and dip of the beds at the surface? Put the symbol on the map.
3. Assuming that the igneous body is the oldest rock in the block,
   a. What is the name applied to the contact between the conglomerate and the igneous body? ________________________________
   b. Write the sequence of events which would account for the structure of the block. (Remember to write the oldest on the bottom.)

5. ____________________
4. ____________________
3. ____________________
2. ____________________
1. ____________________

4. Assuming that the igneous body is the youngest rock in the block, write the sequence of events which would account for the structure of the block.

   4. ______________________________

   3. ______________________________

   2. ______________________________

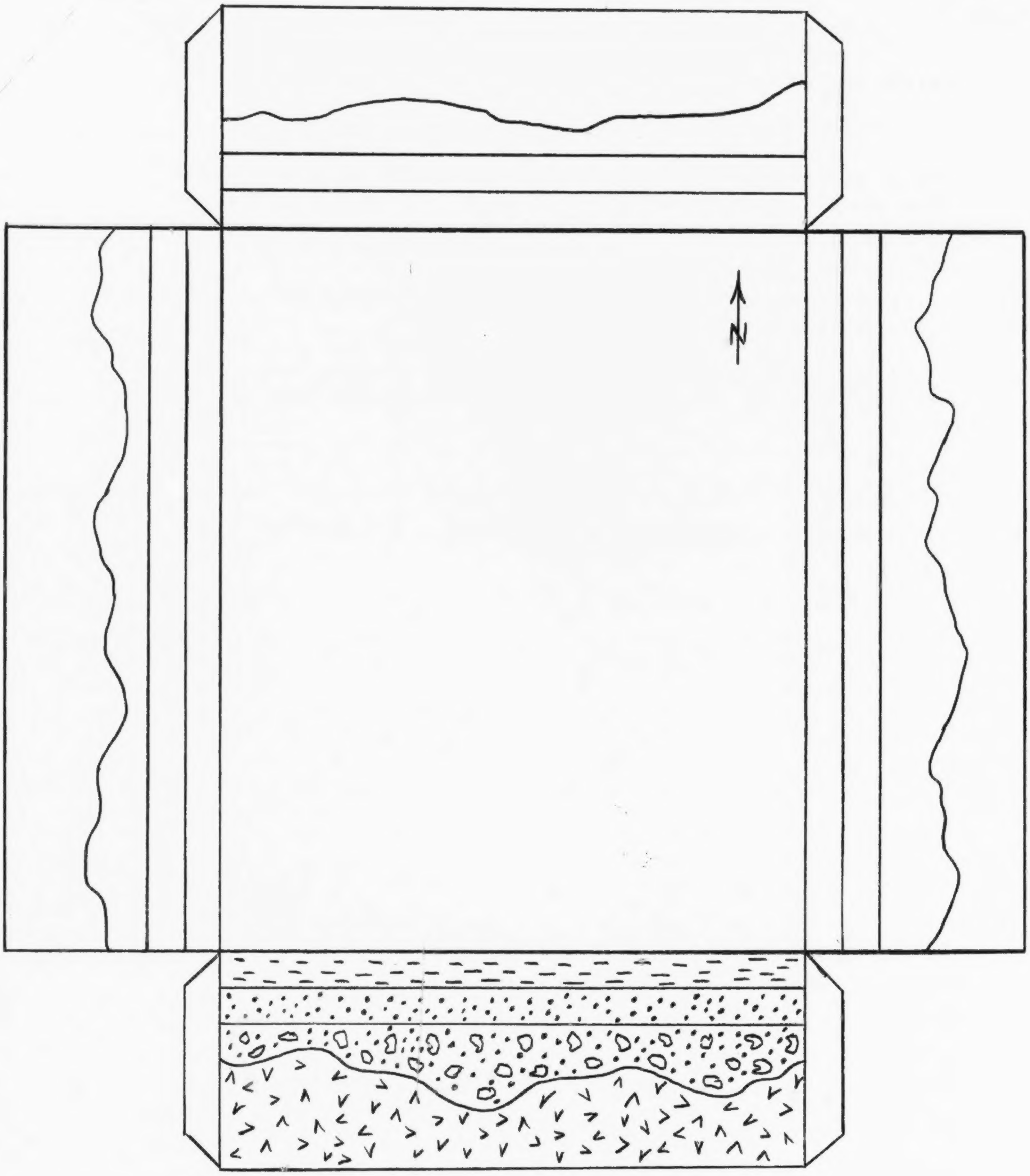
   1. ______________________________

5. If the vertical scale of the block is 1 inch = 1,000 feet and the rate of deposition is 1 inch every 1,000 years, then the depth of the sediments in the southeast corner of the block represents

   ____________________ years of deposition.

LESSON 24, Introduction, Page 5

BLOCK 1



BLOCK 2

1. Complete the block by putting in all of the necessary symbols.
2. What is the strike and dip of the youngest bed? ____________
3. Assuming the younger beds to be eroded away, what would be the strike and dip of the older series of beds?

   Strike ____________ Dip ____________

4. What is the name of the contact between the horizontal series of beds and the dipping series of beds? ____________
5. What is the difference between the contact in question 4 and the contact between the conglomerate and sandstone in the dipping series of beds? ____________

   ____

6. Write a complete sequence of geologic events for this block.

13.

12.

11.

10.

9.

8.

7.

6.

5.

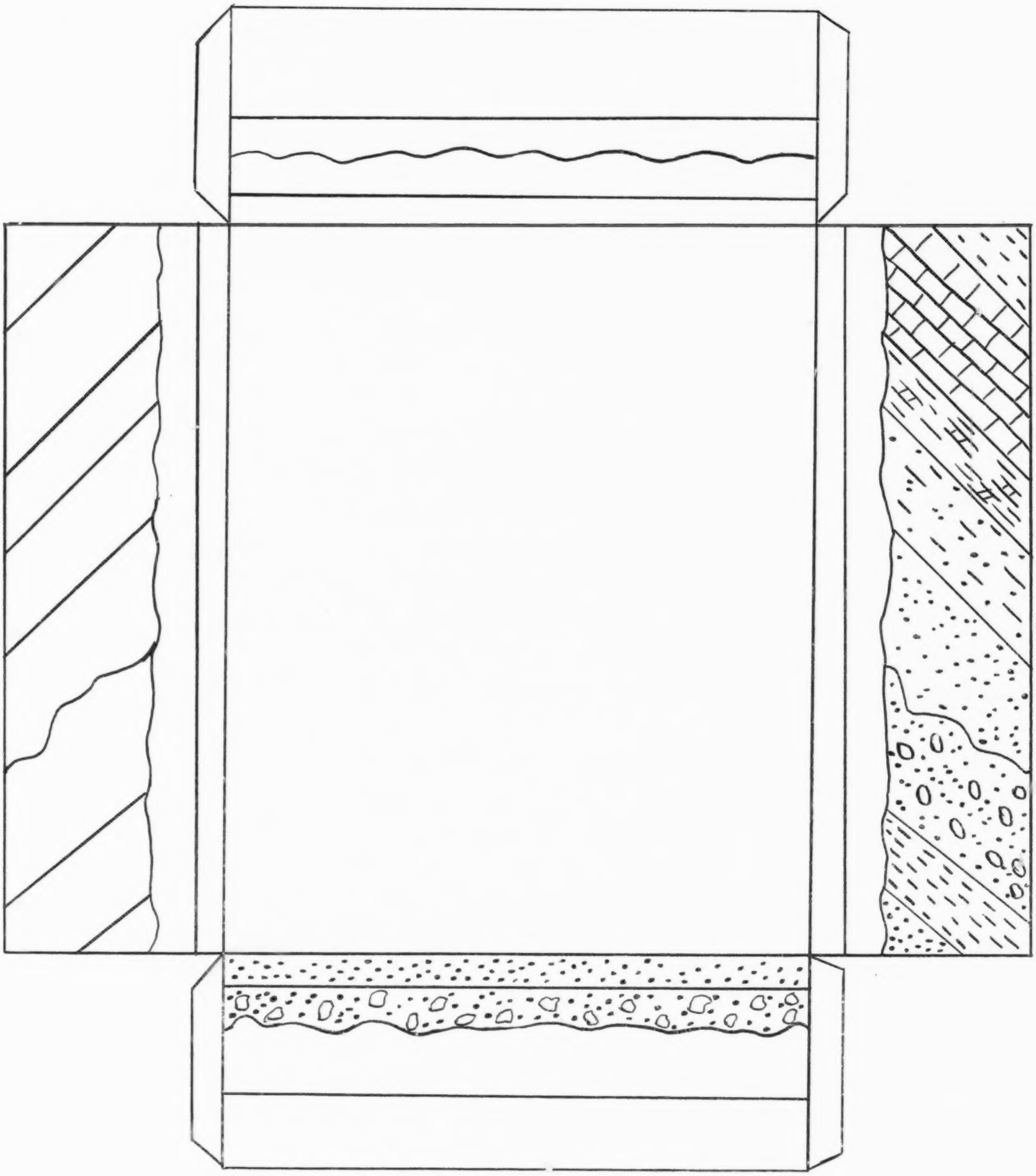
4.

3.

2.

1.

BLOCK 2



BLOCK 3 and BLOCK 4

1. Fill in the necessary symbols and assemble the blocks.
2. What is the structural form of block 3? ______________________
3. What is the structural form of block 4? ______________________
4. What three MAJOR events resulted in the present form of the blocks? (List oldest first)

   3. ______________________

   2. ______________________

   1. ______________________

5. Show the strikes and dips for points A, B, C, D on each block.

Block 3	Strike	Dip	Block 4	Strike	Dip
A.	______	______	A.	______	______
B.	______	______	B.	______	______
C.	______	______	C.	______	______
D.	______	______	D.	______	______

6. Plot the strike and dip for each of the points on the map.
7. Compare blocks 3 and 4. How can you tell the difference between an anticline based on strike and dip symbols? ______________________

   ____

8. How do the ages of the rocks compare as you approach the fold axis of the anticline and the syncline? ______________________

   ____

   ____

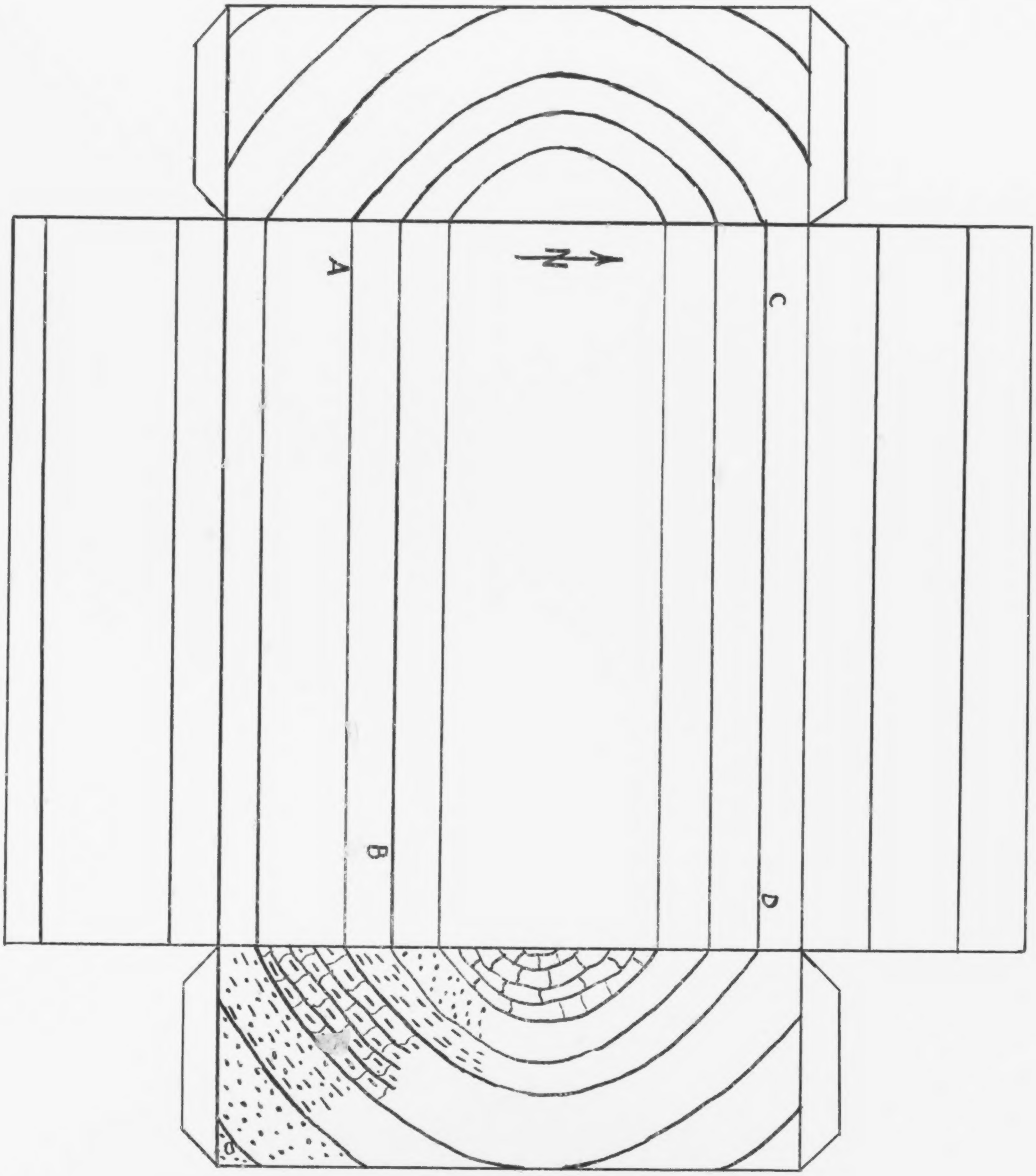
9. Are the oldest rocks found to the inside or the outside of the fold?

   ____

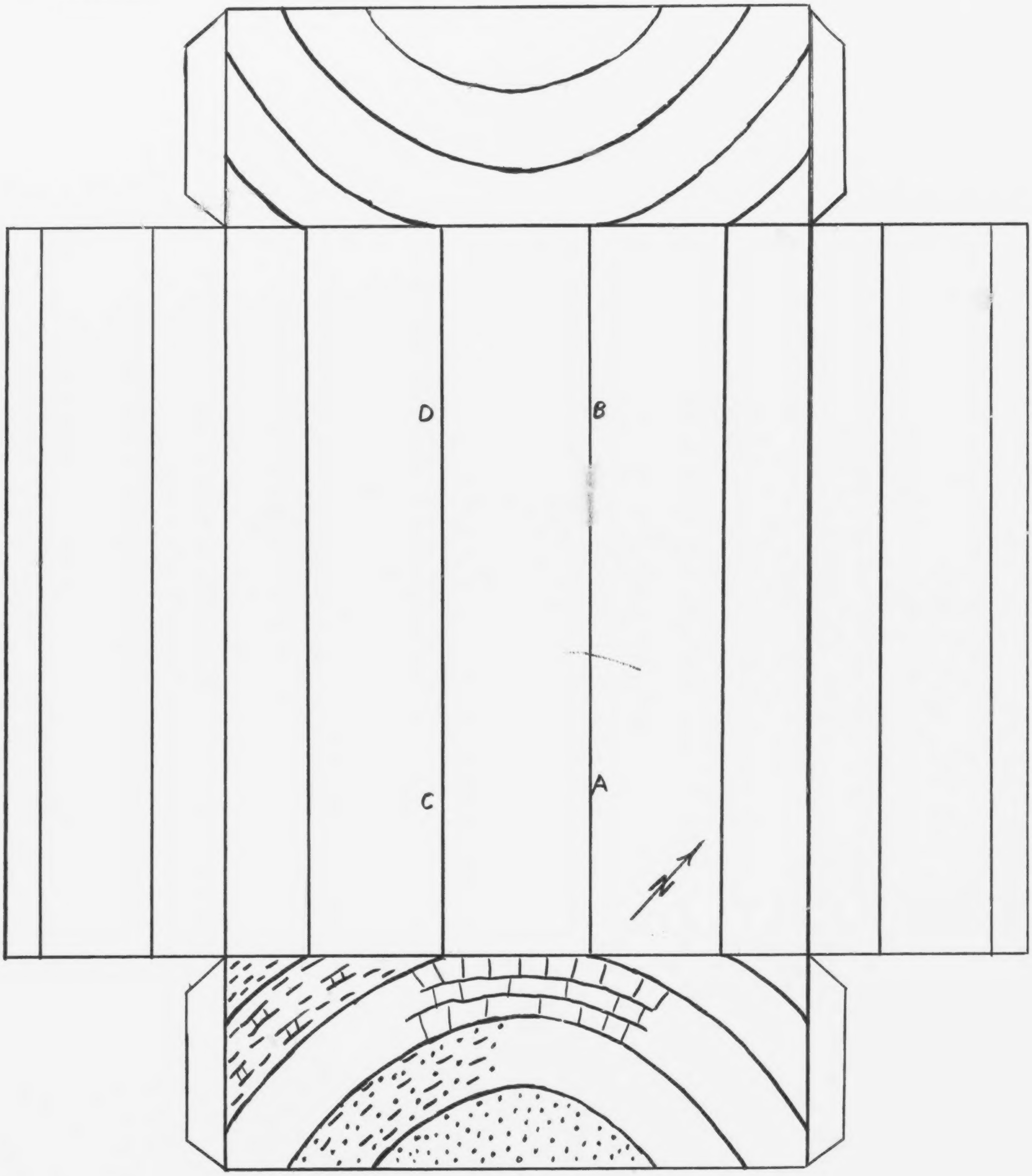
10. Why are the beds parallel on the geologic map on the surface of the block?

   ____

BLOCK 3



BLOCK 4



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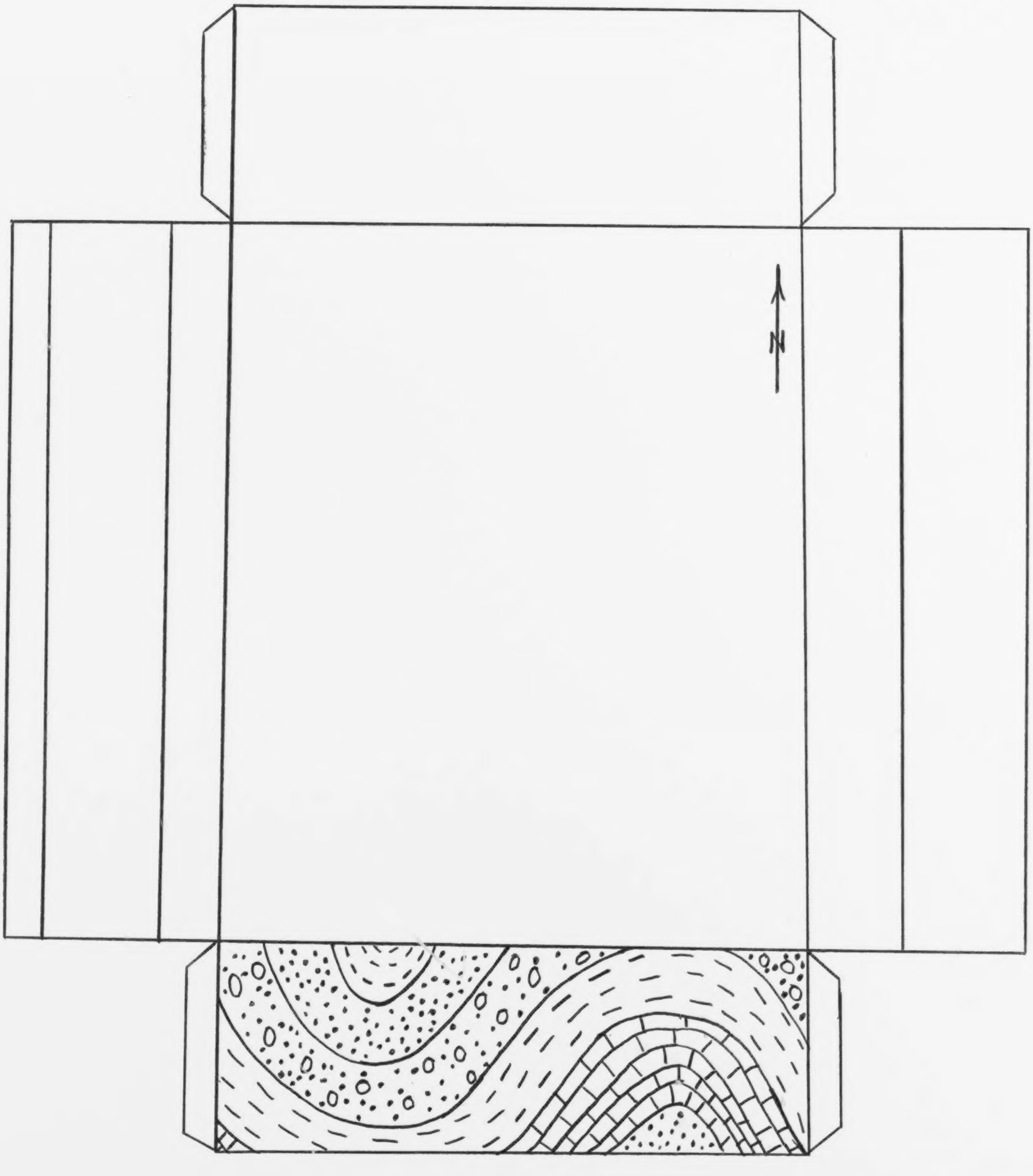
BLOCK 5

1. Fill in all the necessary rock structure.
2. Draw the geologic map on the top of the block. Put in the appropriate strike and dip symbols.

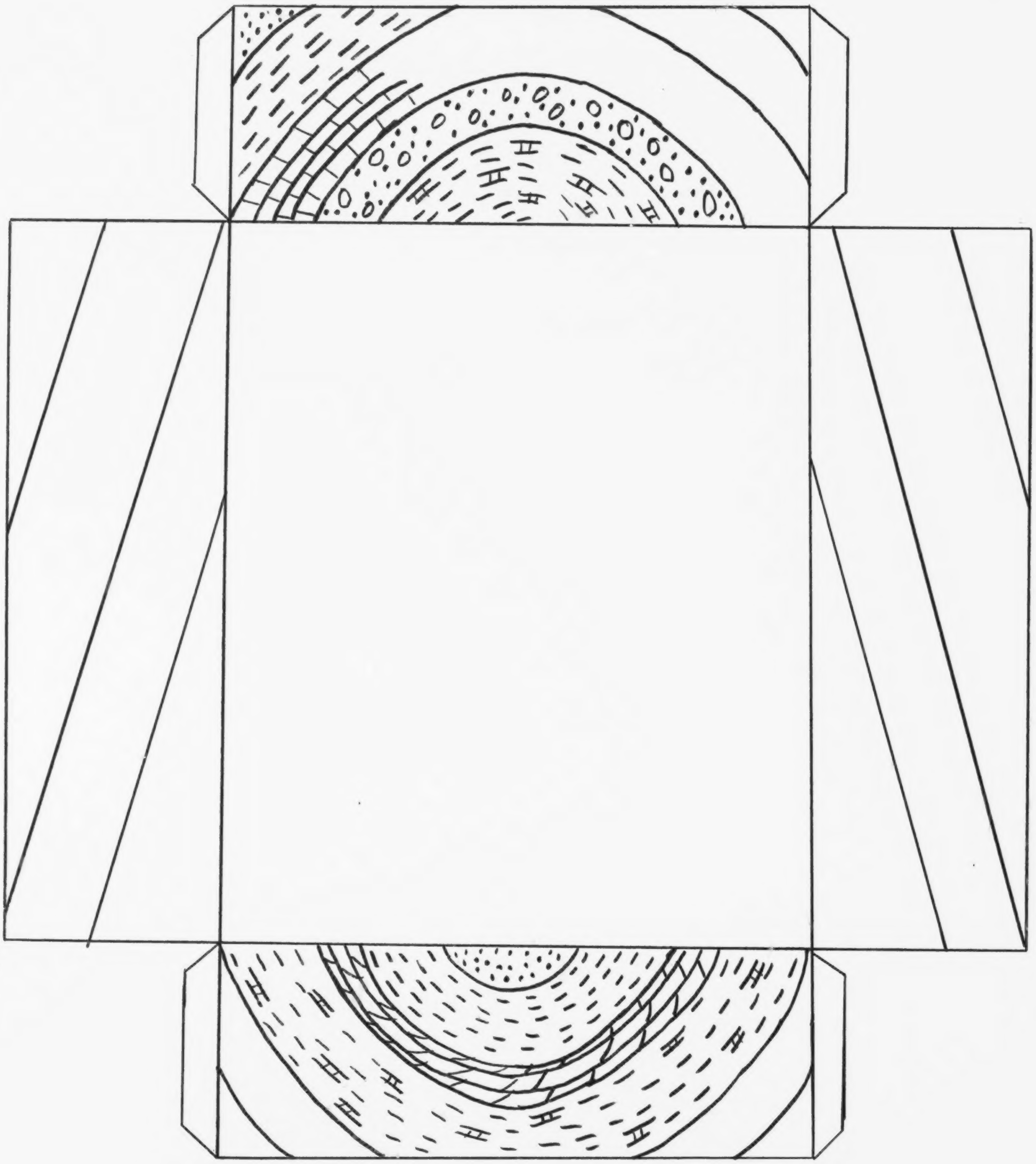


BLOCK 6 and BLOCK 7

1. Fill in all the necessary rock structure and assemble the block.
2. Draw the geologic map on the top of the block. Include strike and dip symbols and symbols showing rock type.
3. What geologic structure is shown in Block 6? ____________________
4. What geologic structure is shown in Block 7? ____________________
5. The structure in block 6 is plunging in what direction? ____________
6. The structure in block 7 is plunging in what direction? ____________
7. What is the angle of plunge for each block?

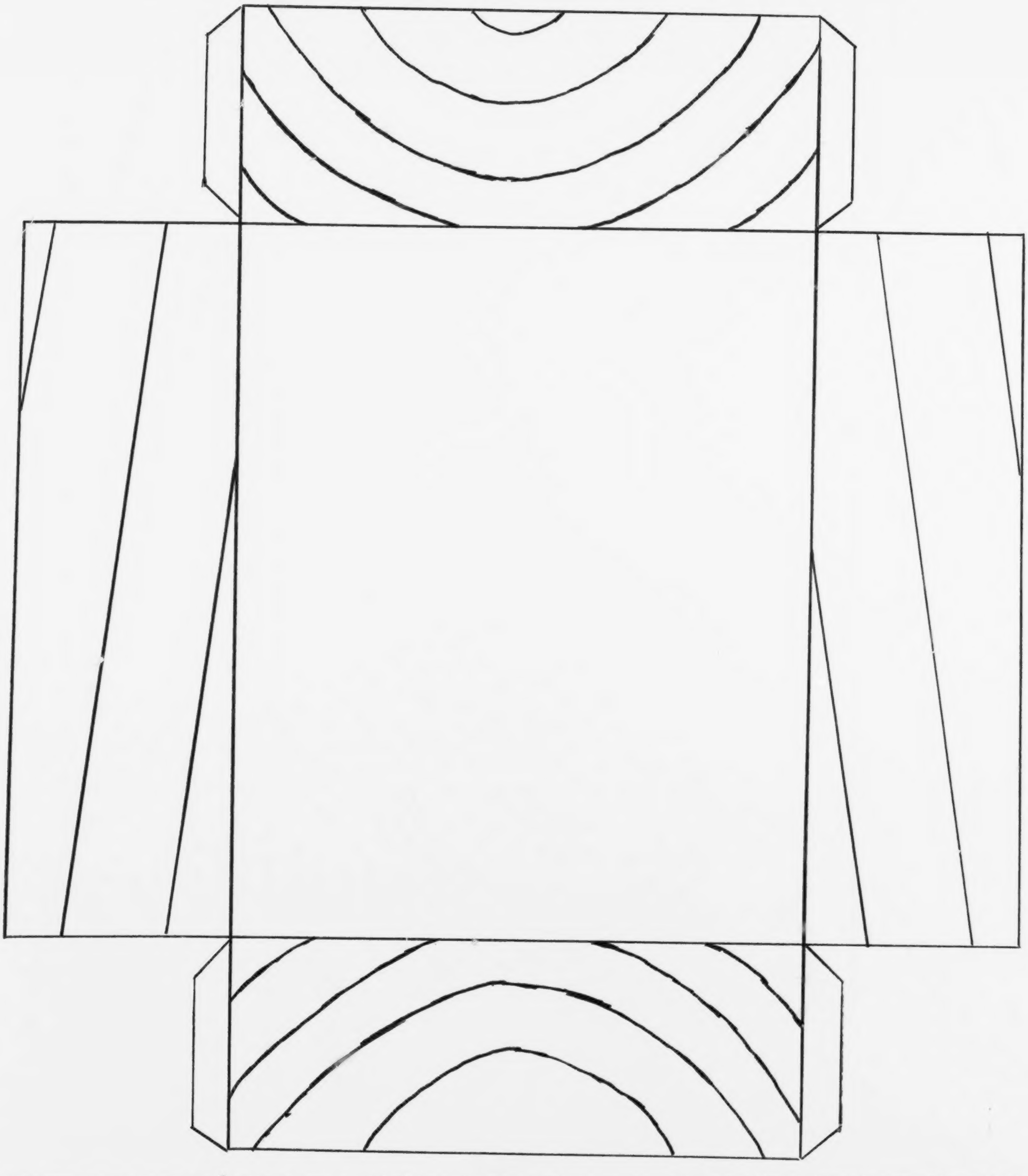
   Block 6 ________________ Block 7 __________________

BLOCK 6



BLOCK 7

Use any rock type symbols you wish. Make sure, however, that they match in the appropriate parts of the block.



BLOCK 8 and BLOCK 9

1. Fill in all the necessary rock structure.
2. What type of fault is block 8? ____________________
3. What type of fault is block 9? ____________________
4. For each of the blocks, has the surface been lengthened or shortened?

   a. Block 8 ______________ b. Block 9 ______________

5. How much has the surface been shortened or lengthened in each block? (Horizontal scale: 1 inch = 1,000 feet)

   a. Block 8 ______________ b. Block 9 ______________

6. How much movement has occurred along the fault plane? (Vertical scale same as horizontal)

   a. Block 8 ______________ b. Block 9 ______________

7. What is the vertical displacement of each of the blocks?

   a. Block 8 ______________ b. Block 9 ______________

8. Match the following labeled points on the diagram to the terms below.

BLOCK 8	BLOCK 9	TERMS
A _____	A _____	1. Fault line 2. Downthrown block 3. Upthrown block 4. Footwall 5. Bedding plane
B _____	B _____	
C _____	C _____	
D _____	D _____	
E _____	E _____	
F _____	F _____	

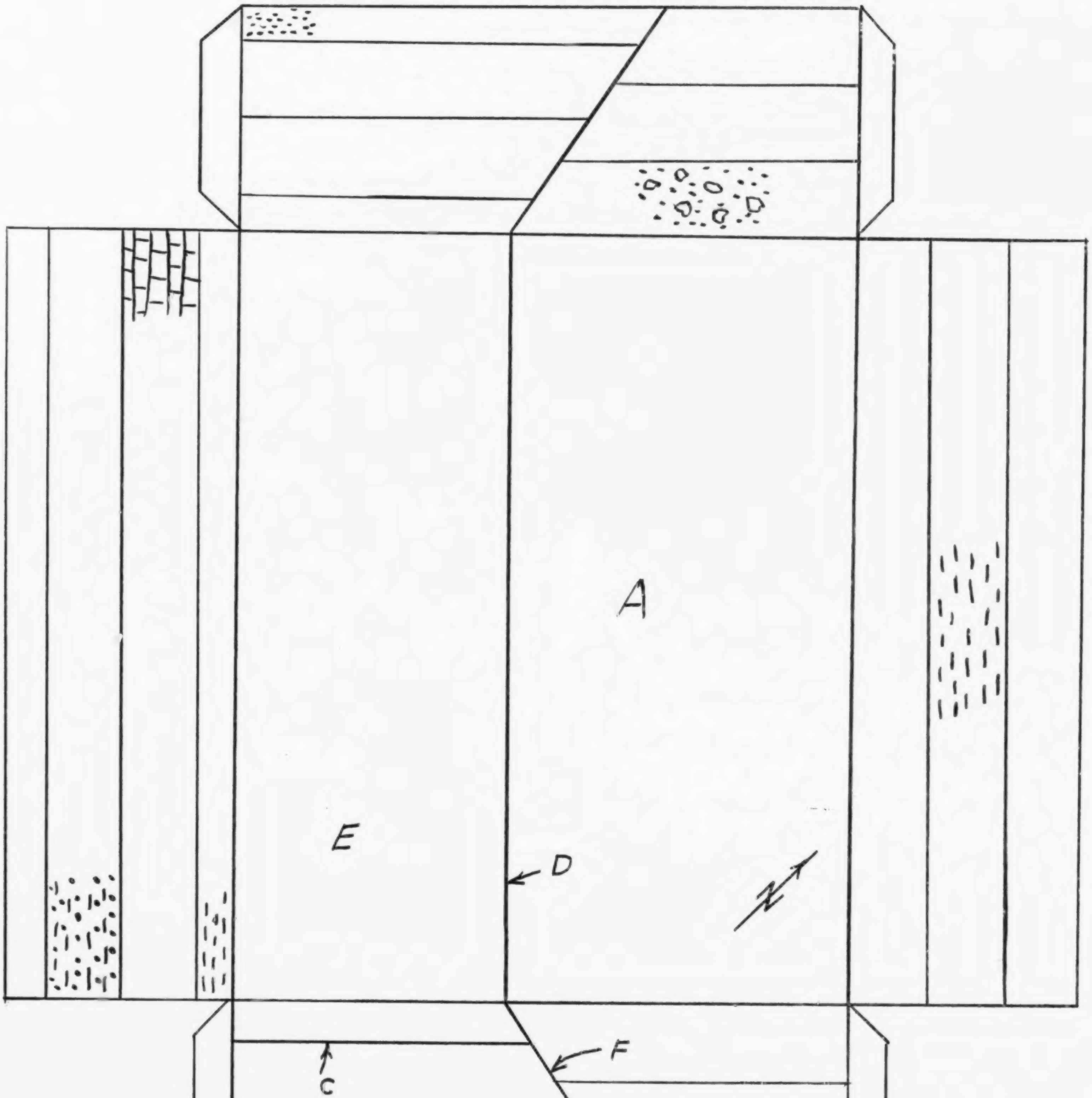
9. What is the strike and dip of each fault?

   a. Block 8 b. Block 9

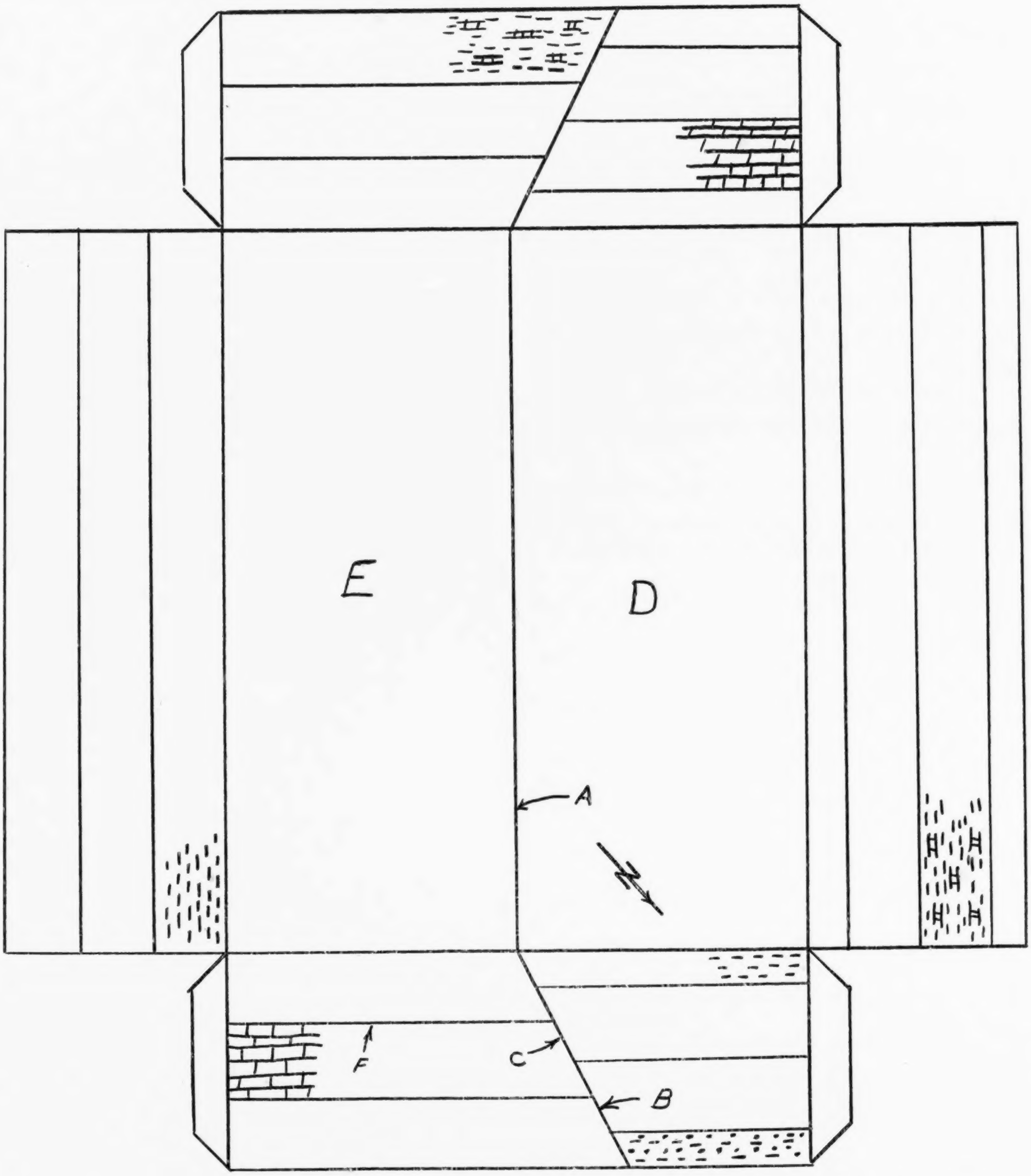
   Strike ______________ Strike ______________

   Dip ______________ Dip ______________

BLOCK 8



BLOCK 9



BLOCK 10

1. Complete the block by putting in all the necessary symbols.
2. Complete the geologic map on the top of the block. Include any necessary strike and dip symbols for both the faults and the sedimentary strata.
3. What two types of faults are shown in this block?

   A ______________________ B ______________________
4. What is the displacement along fault A? (Scale: 1 inch = 1000 feet)

   ____
5. At the same scale, what is the displacement along fault B?

   ____
6. Write a complete sequence of geologic events for this block. Include each sedimentary layer. (Remember, oldest on bottom.)

   11. ______________________
   10. ______________________
   9. ______________________
   8. ______________________
   7. ______________________
   6. ______________________
   5. ______________________
   4. ______________________
   3. ______________________
   2. ______________________
   1. ______________________

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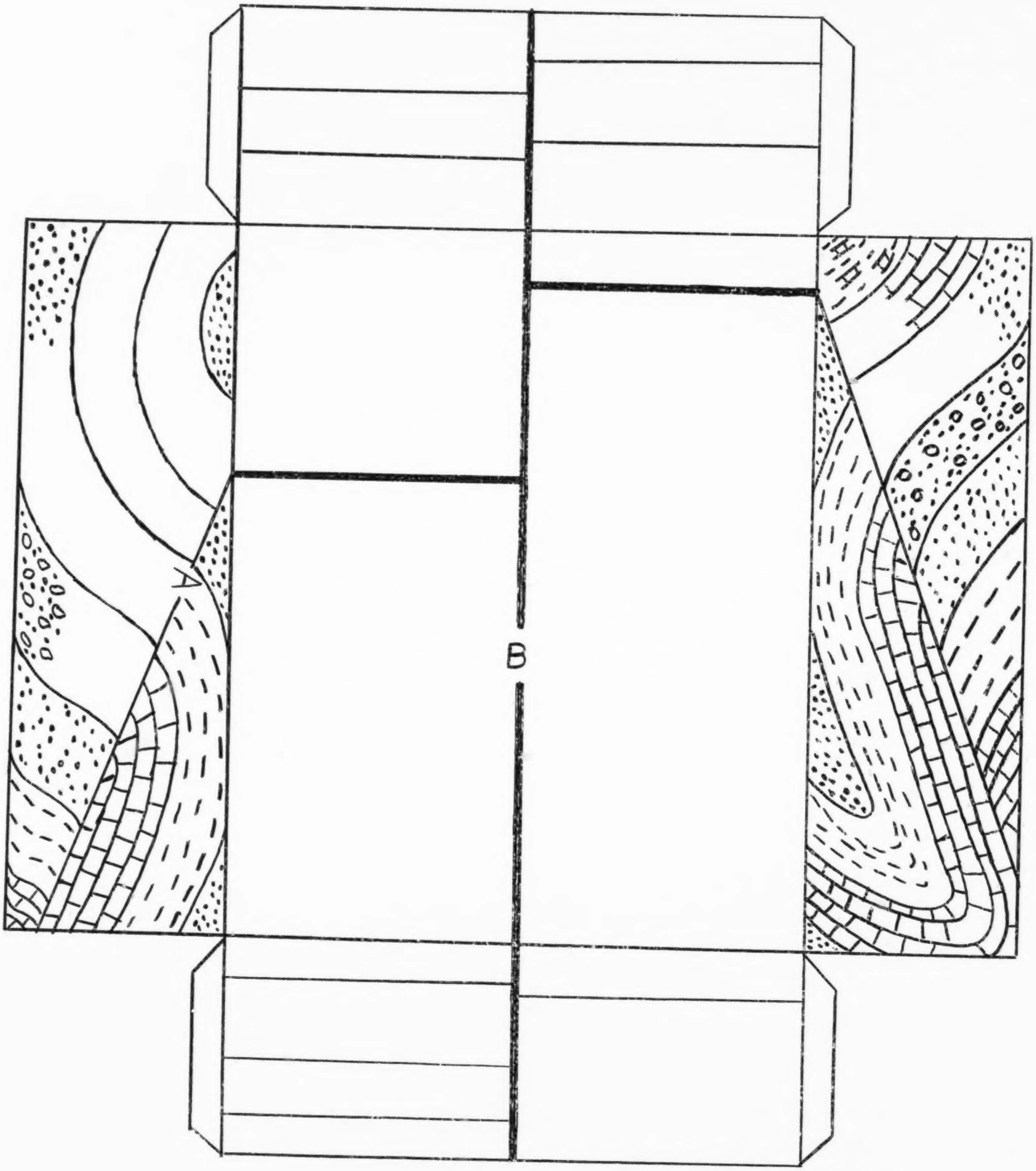
BLOCK 10



LESSON 24

DIASTROPHISM

I. Landforms.

  A. The processes of diastrophism and volcanism are responsible for the major landform features in the United States. Examples: mountains, plains, plateaus, etc.

  B. The geomorphologist classifies landforms according to:

    1. Their structure.

    2. Their topography.

  C. General types of landforms.

    1. Plain - a region of low relief and horizontal rock structure (maximum relief = one or two hundred feet).

    2. Plateau - a region of horizontal rock structure with high relief (more than 1,000 feet).

    3. Mountains - landforms with a relief greater than 2,000 feet, and a rugged summit of relatively small area.
    NOTE: All true mountains are composed of rock masses in a nonhorizontal or disturbed position. They may be tilted, folded, domed, or built up of volcanic material.

II. Life History of Landforms.

  A. Constructional processes are constantly opposed by destructional (erosional) processes.

  B. Constructional landforms are almost never seen in their initial state.

  C. Ideally landforms pass through three stages of development.

    1. Youth.

    2. Maturity.

    3. Old age.

  Taken together, they make up the life history of the landform.

  D. Landforms do not always complete the cycle. A mature plain may be uplifted long before it has reached old age; entering instead into a youthful stage again.

E. Definitions of life stages:

1. Youth - landscape has rugged topography with steep slopes and deep narrow valleys.

2. Maturity - surface is much cut up and shows a great variety of features.

3. Old age - landscape is worn down and most features are destroyed.

a. The flat surface resulting is called a peneplain (almost a plain).

b. When uplift rejuvenates a peneplain, the topography is determined by the nature of the rocks that originally formed the surface.
NOTE: Piedmont North Carolina is a dissected peneplain. The area was eroded almost to sea level and then uplifted, allowing the streams to cut down into the plain surface.

c. Unconformities - result when tilted sedimentary beds are covered by horizontal beds which cut across them. This indicates tilting, followed by erosion, followed by deposition.

d. Disconformities - occur when erosion interrupts a depositional sequence and deposition resumes with no change in the attitude of beds, either above or below the disconformity.

F. Structural relationships are good clues to the history of a region.

III. Before the Eighteenth Century, men attributed past and present landforms to sudden catastrophies.

A. In 1785, James Hutton introduced his theory of uniformitarianism to the Royal Society of Edinburgh.

B. Hutton's theory stated that "the present is the key to the past."

1. The forces acting today are the same forces that have been acting throughout the ages.

2. A slow, gradual process of building up by earth movement and wearing down by erosion is responsible for most of the landforms present today.

IV. The Language of Landforms.

A. Physiography is the branch of the earth sciences that deals with the earth's surface features. It includes the earth's climates, the ways man makes use of the soil, waterways, and many other resources of our planet. It emphasizes landforms as to their effect on man.

B. Geomorphology is the branch of earth science that emphasizes landforms as such. It considers their origins, the changes they undergo, and their past histories.

V. Diastrophic forces are those that cause the movement of parts of the earth's crust.

VI. Diastrophism and volcanism are very closely related. Diastrophism deals with movements of the solid portions of the crust while volcanism deals with movements of magma.

A. There are three types of diastrophic movements:

1. Uplift - A local or widespread rising of the crust.

2. Subsidence - Sinking of the earth's crust.

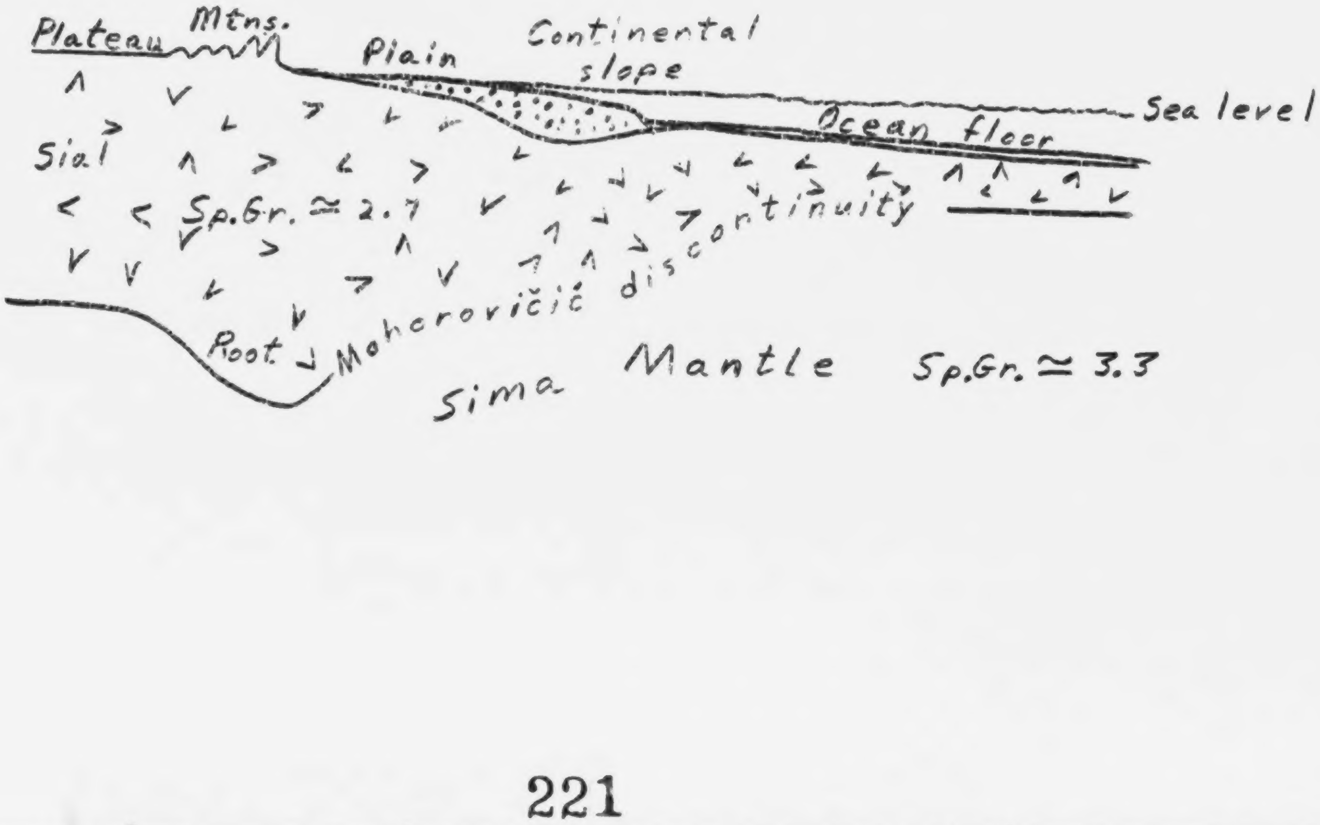
3. Thrust - A horizontal motion of the crust, by which large masses of rock slide against one another into new positions. (Easily seen along San Andreas rift and at Chief Mountain, Montana.)

B. Causes of diastrophism.

1. Theory of isostasy. (Greek; means "equal standing")

a. Solid rock is somewhat plastic under certain conditions. It flows and changes shape when subjected to a great pressure.

b. One may think of the crust as consisting of lighter, granitic continental material and heavier, basaltic ocean basin material.


Plateau
Mtns.
Plain
Continental slope
Sea level
Ocean floor
Sial
Sp.Gr. ≃ 2.7
Mohorovičić discontinuity
Root
Sima
Mantle
Sp.Gr. ≃ 3.3

c. Under normal conditions, any region in which sediments are being deposited will subside under the weight of the newly deposited material. Such subsiding basins are called geosynclines. Material deposited in geosynclinal basins may reach enormous thicknesses.

d. When subsidence occurs due to increase in weight, an adjustment by subsurface rock "flow" results in uplift or emergence of other areas.

VII. Deformation of rocks.

Diastrophism results in forming metamorphic rocks. Diastrophic forces cause bends, breaks, and distortions in rocks.

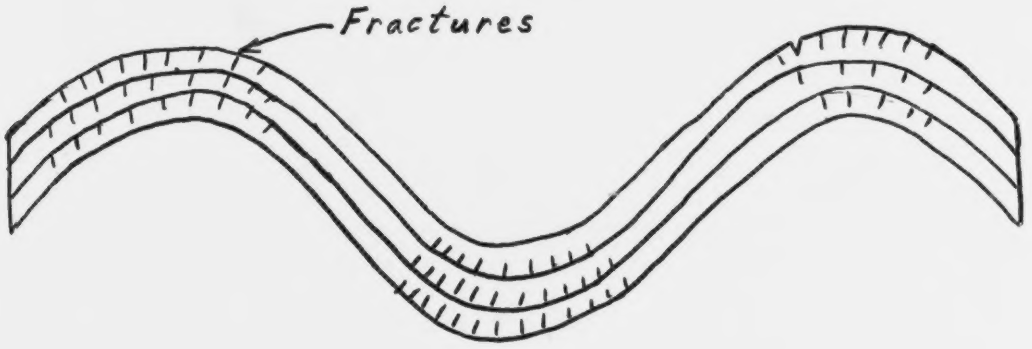
A. Pronounced and continued pressure may cause rocks to be deformed into wave-like folds.

1. The folds may range in size from inches to miles in length.

2. The larger folds may be responsible for mountain ranges such as the Appalachians.

3. The folding of rock under these conditions is called plastic deformation.

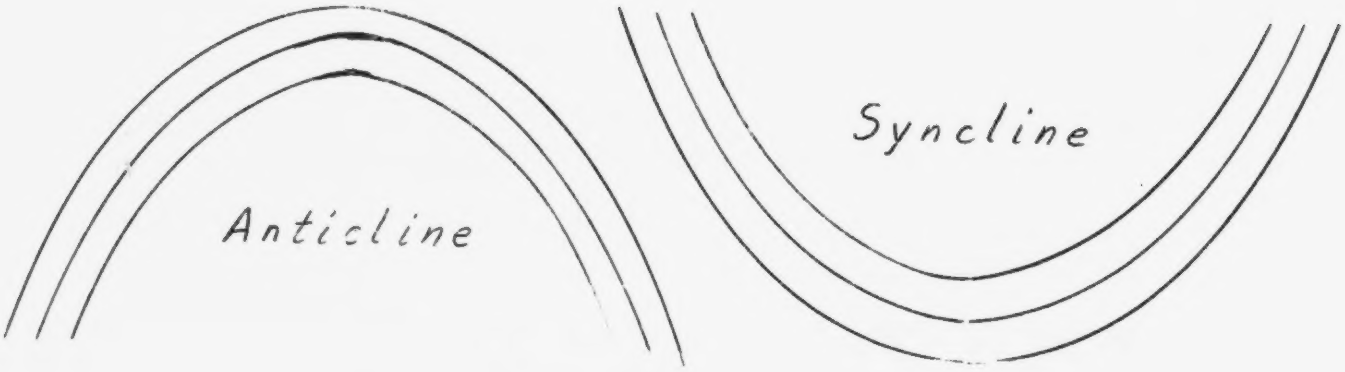
B. Along with the folding there may also be breaking (fracturing) and movement along the breaks (faulting).



VIII. Folding - During uplift there is almost always some warping of sedimentary beds. This results in shallow or steep domes and basins depending on the amount of deformation involved.
(Example: San Rafael Swell, Colorado Plateau)

A. The crest of rock fold is called an anticline.

B. The trough of a rock fold is called a syncline.

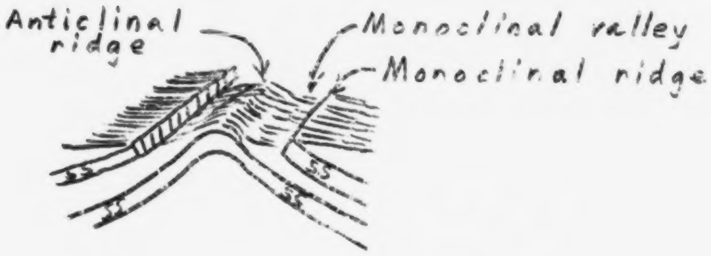

Anticline
Syncline

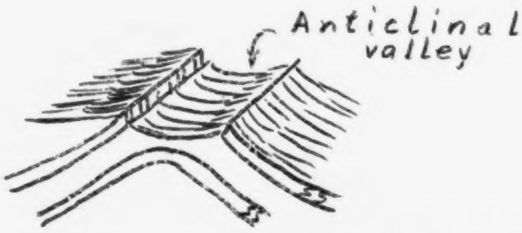
C. If these structures could be seen uneroded, then the anticlines would be hills and the synclines valleys. (Example: Fingers of the Cascades into the Columbia Plateau)

D. More often, however, only the eroded folds can be seen.

E. Normally erosion is more active at the top of anticlines.

F. As erosion continues, it may eventually form ridge and valley topography. (Example: Shenandoah Mountains, Virginia)


Anticlinal ridge
Monoclinal valley
Monoclinal ridge
SS
SS
SS
SS


Anticlinal valley
SS
SS

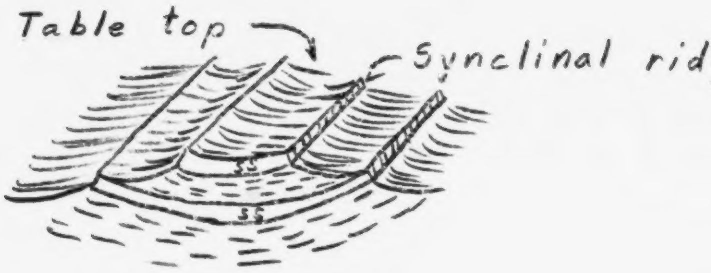
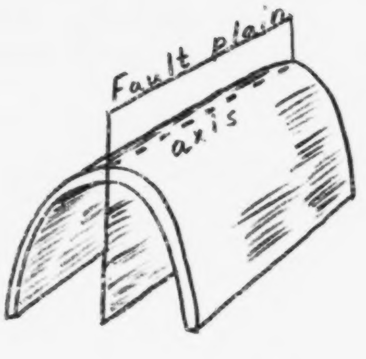


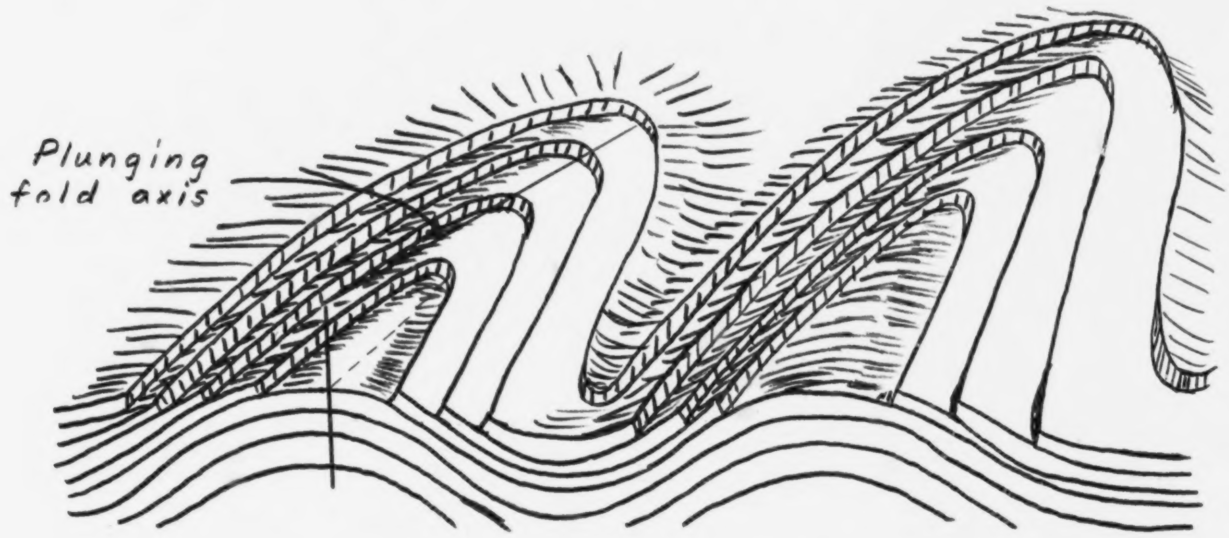
Table top
Synclinal ridge
SS
SS


Fault plain
axis

G. Erosion may even convert the synclines into mountains if it is extensive enough.

H. Pitching folds: folds cannot continue indefinitely.

1. An imaginary line running along the top of an anticline or bottom of a syncline is called the fold axis.
2. If the axis is horizontal, or nearly so, the ridges formed will be roughly parallel.
3. If the axis enters the ground at an angle (plunges), the result will be a cigar-shaped series of beds after erosion.
4. If the axis plunges in both directions, a basin or dome may result.



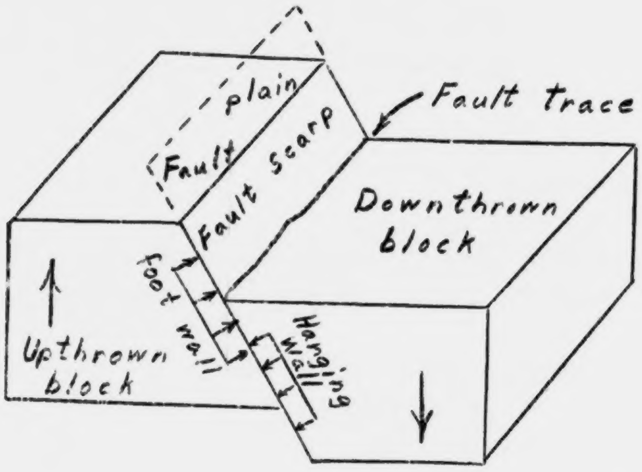
IX. Fractures may develop for a number of reasons-- cooling of a rock mass, release of pressure, folding, etc.: A joint is a crack along which no movement has taken place and where there is no space between the surfaces of the joint; A fissure is a crack that has expanded creating a space between the surfaces; Elastic deformation and plastic flow eliminate joints and fissures at depth; Joints and fissures due to other causes are also found in sedimentary rock and in metamorphic rock, but those due to folding can usually be distinguished by their relationship to the dip of the rock.

A. Faulting occurs if any slippage takes place along a joint or fissure.

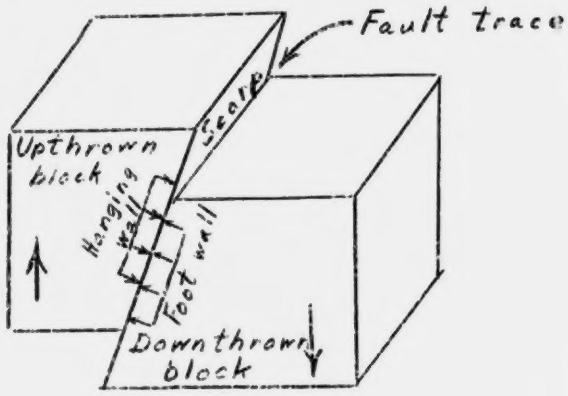
1. Fault nomenclature (types of faults):

a. Vertical faults.

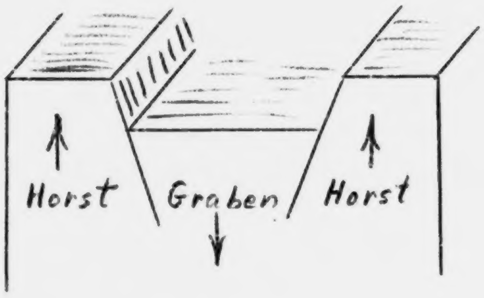
1) Normal (gravity) fault - hanging wall has moved down relative to the footwall.


Fault plain
Fault scarp
Fault trace
Downthrown block
foot wall
Hanging wall
Upthrown block

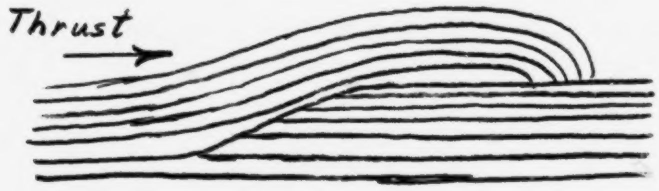
2) Reverse fault - hanging wall has moved up relative to the footwall.


Fault trace
Scarp
Upthrown block
Hanging wall
foot wall
Downthrown block

3) Horst and Graben.


Horst
Graben
Horst

b. Horizontal (thrust) faults.



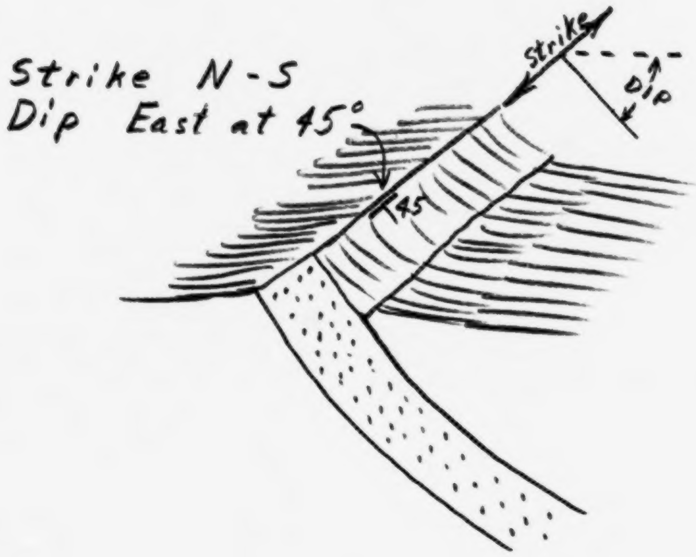
B. Strike and Dip.

1. A geologic map or diagram shows the direction and tilt of a rock bed in terms of strike and dip.

2. The device used to determine the strike and dip of a bed is called a Brunton Compass. (Contains clinometer for dip and compass for strike.)

   a. A clinometer is a pendulum mounted so as to show the amount of tilt of a bed, from the horizontal, when placed on the bed's surface. (Dip)

   b. A compass measures the direction in which a bed runs along the surface. (Strike)



3. Strike and Dip may be measured for faults, joints, and folds.

LESSON 25, Introduction

DIASTROPHISM-- EARTHQUAKES AND METAMORPHISM

Objectives:

1. To gain an understanding of the processes resulting in the generation of seismic waves.
2. To develop a concept of the behavior of seismic waves and the internal structure of the earth that has been determined by their interpretation.
3. To relate metamorphism to diastrophism and develop a concept of the process of metamorphism.
4. To recognize the various types of metamorphic rocks and to understand how they are related to and how they indicate the processes which they have undergone.

References:

1. THE EARTH-SPACE SCIENCES, Chapters 13, 14, and 22.
2. FOCUS ON EARTH SCIENCE, Chapters 7 and 18.
3. INVESTIGATING THE EARTH, Chapters 15 and 16.

Special References:

Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 10 and 11.

Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapters 19 and 30.

Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 7 and 25.

Gilluly, et al. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company), Chapters 18 and 19.

Pirrson and Knopf. ROCKS AND ROCK-MINERALS (John Wiley & Sons, Inc., New York), Chapters 12 and 13.

Activities:

1. Investigating rocks from the cores of mountains
   ESCP 15-1 Text 332
   Teacher's Manual 409-411

2. Investigating the inside of a sphere
   ESCP 16-1 Text 350
   Teacher's Manual 443-444

3. Locating the epicenter of an earthquake
   ESCP 16-4 Text 354-355
   Teacher's Manual 446-448

4. Investigating patterns of change-- Earthquake Watch
   ESCP 1-7 Text 25, 26, 27
   Teacher's Manual 49-51

Have students make a scale model of a cross section of the interior of the earth. Using a scale of 12" = 8000 miles, they should be able to determine the relative thickness of each of the sections of the inner earth.

RELATIVE THICKNESS OF LAYERS OF THE EARTH

Crust	25 miles	=	.04 inches
Mantle	1800 miles	=	2.7 inches
Outer Core	1300 miles	=	1.9 inches
Inner Core	900 miles	=	1.4 inches (to center)

If the students are familiar with ratio and proportions, have them use this method to compute the above scale. (The thickness of the crust would have to be represented by a thin pencil line.)

Example:

$$\frac{\text{diameter of earth (scale)}}{\text{diameter of earth}} = \frac{\text{thickness of section (scale)}}{\text{thickness of section of earth}}$$

or as computed for mantle:

$$\frac{12}{8000} = \frac{N}{1800}$$

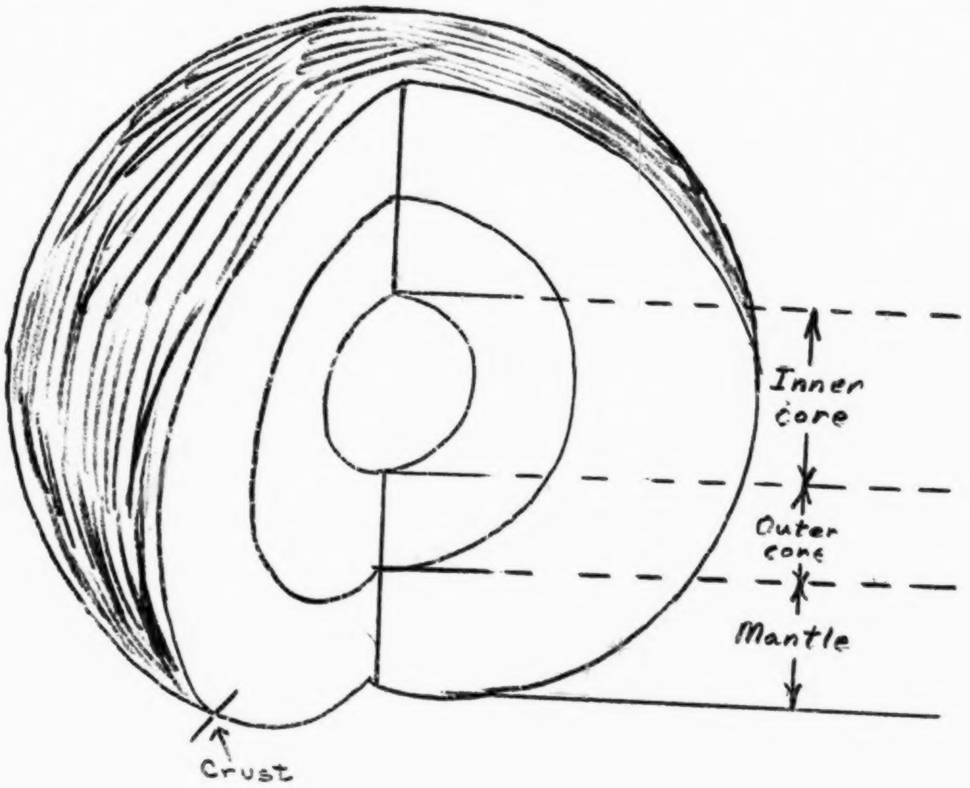
$8000\ N = 12 \times 1800$ Cross multiplying

$8000\ N = 21{,}600$

$\frac{8000\ N}{8000} = \frac{21{,}600}{8000}$ Dividing both sides by 8000

$N = 2.7$ inches

On the basis of the same scale (12 inches = 8000 miles) have the students compute the relative height of Mt. Everest (about 5.5 miles) above sea level. This should give some indication of the smallness of the earth's surface features as compared with the diameter of the earth.


Inner core
Outer core
Mantle
Crust

LESSON 25

DIASTROPHISM-- EARTHQUAKES AND METAMORPHISM

I. Movement of great rock masses within the crust is related to the formation of metamorphic rocks.

   A. Movement of these rock masses is the cause (not the result) of earthquakes.

   B. Most earthquakes are the result of movement along an existing fracture in the deep rock beds.

      1. The walls of a fault are usually very closely pressed together.

      2. Beds under stress go through many years of increasing pressure before they move along a fracture.

         a. This stress often results in the metamorphasing of the rock beds involved.

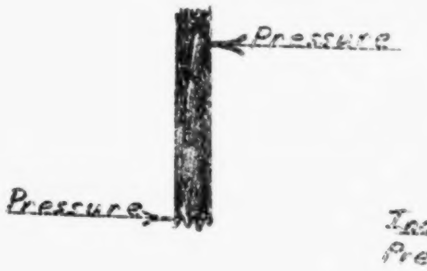
         b. When the stress becomes so great that it exceeds the strength of the rocks, a sudden movement occurs relieving the pressure.

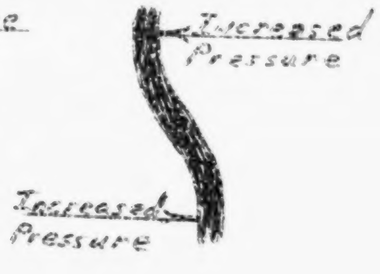
         c. This movement causes seismic waves called an earthquake.

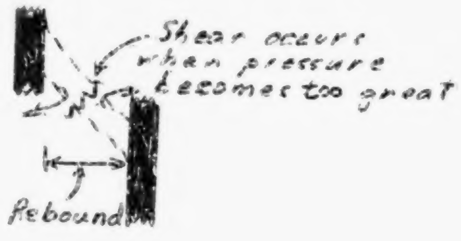
   C. Elastic rebound theory.

      1. Pressure exerted on two adjacent rock areas from opposite directions (may be any direction) for a long period of time causes the rocks to bend slowly as strain increases.

      2. Finally the strain becomes so great that the rocks break and rebound.







Example: San Andreas Fault, California
In 1906 Earthquake, 21 feet of horizontal displacement was noted at several locations along the fault.

D. There are thousands of known faults all over the earth.

  1. Few seem to be active sources of earthquakes.

  2. Most earthquakes probably have their origin below the earth's surface.

E. Earthquakes may be so strong as to affect an entire continent, or more probably, so light that sensitive instruments are needed to record their presence.

F. Tsunamis-- are seismic sea waves sometimes caused by earthquakes occurring under the ocean. They are famous for causing vast destruction when they strike land.

II. Earthquakes occur over the entire earth but are most frequent and most severe along two great belts.

A. These belts are areas of crustal weakness.

  1. One belt circles the Pacific Ocean. (More than 90% of the large earthquakes occur in this belt.)

  2. The second belt includes the Alpine region of Europe, the Mediterranean area, and a section across Asia.

B. While they do not coincide exactly, the earthquake belt and the areas of volcanic activity are closely related.

  1. These active zones are regions whose mountains are of recent formation.

  2. The areas outside the regions of earthquakes are not entirely free of tremors, but the great majority of earthquakes do occur in these belts.

C. Another area of earthquakes occurs along the Mid-Atlantic ridge.

  1. These earthquakes reveal the location of a deep canyon or rift going down the center of the ridge or mountain belt.

  2. This rift coincides with an immense oceanic belt that probably continues around the earth and is related to the known earthquake belts previously discussed.

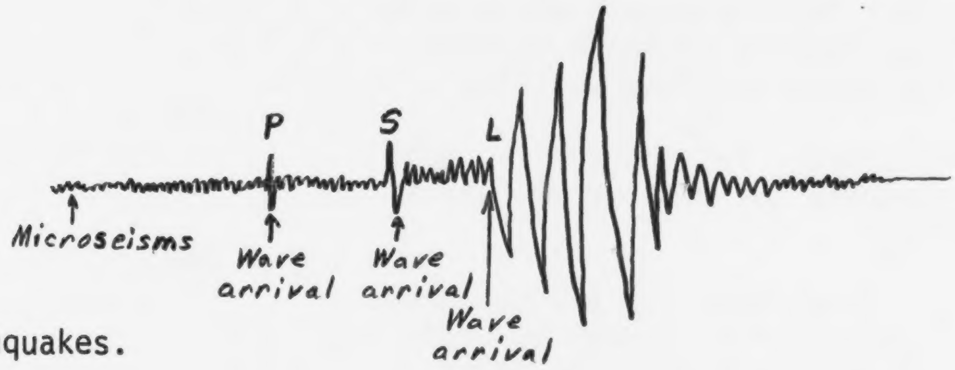
III. Detection of earthquakes.

A. When an earthquake occurs, vibrations go out in all directions.

  1. The focus is the center or source of the shock.

  2. The epicenter is the point or line on the surface directly above the focus.

B. The vibrations are detected by a device called a seismograph. The record made by a seismograph is called a seismogram.



IV. Locating earthquakes.

A. Most quakes occur between 5 and 15 miles below the earth's surface. Some have been recorded as much as 420 miles below the surface.

B. There are three basic types of waves that travel out from the focus of the earthquake. Each has its own characteristic speed and pattern of behavior.

1. Primary waves (pressure - fastest travelers).

2. Shear waves.

3. Longitudinal waves (surface waves).

C. Primary and shear waves travel through the earth as well as along the surface, and have revealed much about the interior of the earth.

D. Seismographs measure the intensity of an earthquake.

1. Intensity is measured in terms of its effects on man.

2. Most common scale is the "Modified Mercalli Intensity Scale."

SCALE OF EARTHQUAKE INTENSITIES WITH APPROXIMATELY CORRESPONDING MAGNITUDES

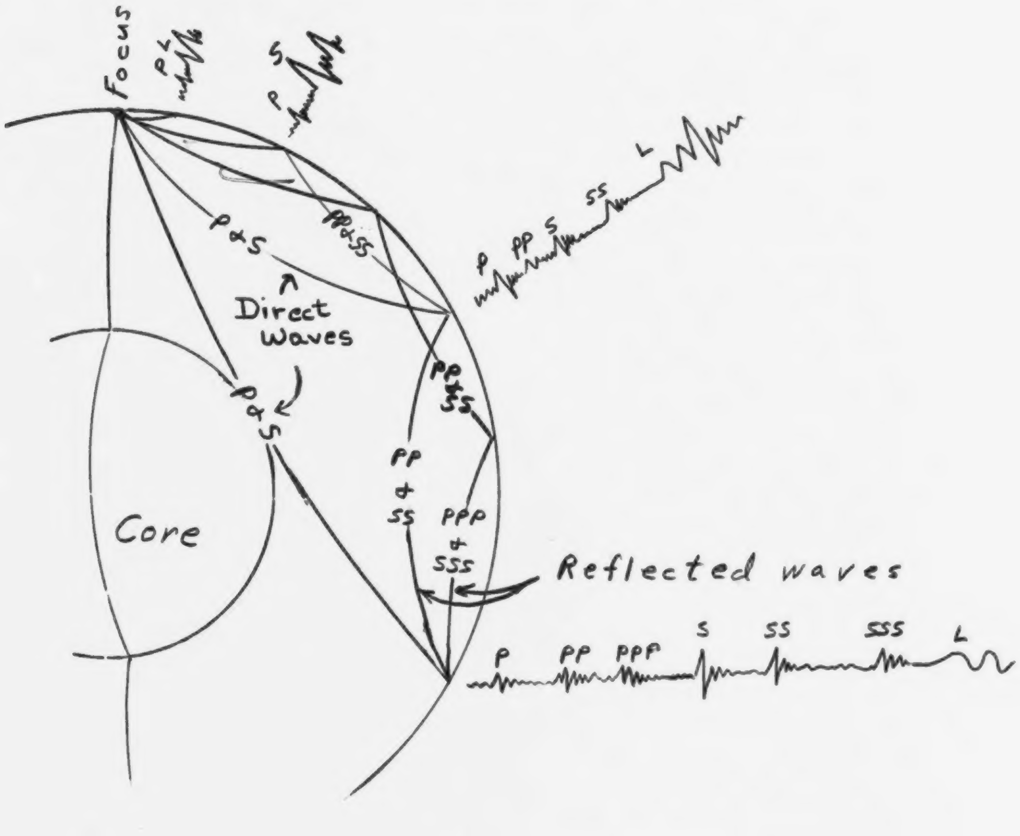
Intensity	Description of characteristic effects	Maximum acceleration of the ground	Magnitude corresponding to highest intensity reached
I	Instrumental: detected only by seismographs		
		10	
II	Feeble: noticed only by sensitive people		3·5
		25	
III	Slight: like the vibrations due to a passing lorry; felt by people at rest, especially on upper floors		to 4·2
		50	

Intensity	Description of characteristic effects	Maximum acceleration of the ground	Magnitude corresponding to highest intensity reached
IV	Moderate: felt by people while walking; rocking of loose objects, including standing vehicles		4·3 to 4·8
		100	
V	Rather Strong: felt generally; most sleepers are wakened and bells ring		
		250	
VI	Strong: trees sway and all suspended objects swing; damage by overturning and falling of loose objects		4·9-5·4
		500	
VII	Very Strong: general alarm; walls crack; plaster falls		5·5-6·1
		1,000	
VIII	Destructive: car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed buildings damaged		6·2 to 6·9
		2,500	
IX	Ruinous: some houses collapse where ground begins to crack, and pipes break open		
		5,000	
X	Disastrous: ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes		7-7·3
		7,500	
XI	Very Disastrous: few buildings remain standing; bridges destroyed; all services (railways, pipes and cables) out of action; great landslides and floods		7·4-8·1
		9,800	
XII	Catastrophic: total destruction; objects thrown into air; ground rises and falls in waves		>8·1 (maximum known, 8·9)

E. Artificial earthquakes may be generated by explosions to study the structure beneath the surface of the earth. This has been especially useful in searching for oil.

V. Seismic waves reveal the structure of the earth. Scientists know more about the Universe than they do about the earth only a few miles beneath the surface.

- A. The knowledge we possess about this region (a few miles beneath the surface) has been gained in two ways:
  1. Inference from the structure of the surface.
  2. Geophysical studies using instruments of varying types.
- B. Seismic (earthquake) waves have been used by scientists (geophysicists) to determine the interior form of the earth.
  1. P, S, and L waves are created by an earthquake of underground explosion.
  2. Each type of wave behaves in a certain manner.
     - a. Certain types of waves will travel through solids but not through liquids.
     - b. Waves are bent (deflected) by materials of varying density.


Focus
P L
P S
P&S
PP&SS
Direct Waves
P&S
Core
PP&SS
PP & SS
PPP & SSS
Reflected waves
P PP S SS L
P PP PPP S SS SSS L

C. Seismic waves have revealed the structure of the interior of the earth-- to some degree.

1. The ability of a wave to travel through the earth indicates whether the material is in a solid or liquid state.

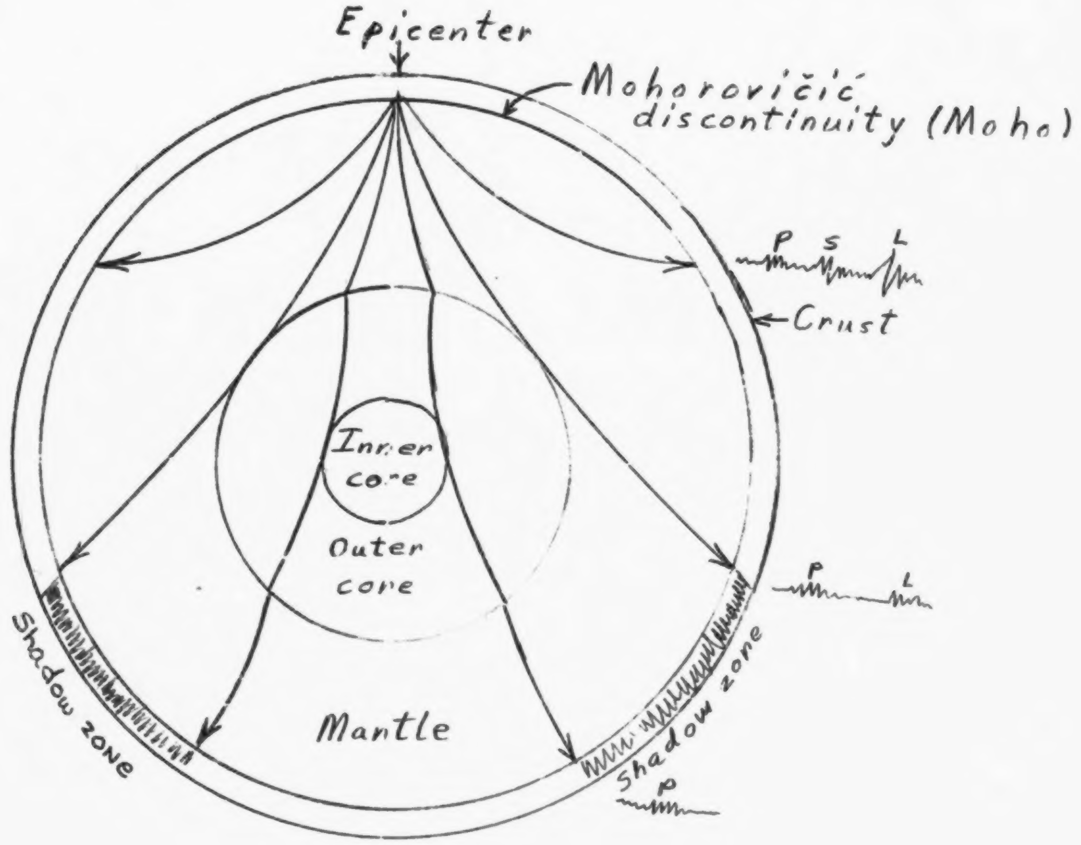
2. The velocity of a wave tells us something about the density of the solids inside the earth.

3. The bending reveals the structural arrangement of the materials (on a large scale only).

4. Study of these waves disclosed a shadow zone which, along with other data, has revealed the general structure of the interior of the earth.

5. Seismic wave velocity studies have revealed a difference between the mantle and the outermost layer of the earth's crust.

   a. In 1909 a Yugoslav scientist-- Alexander Mohorovičić discovered a region between the crust and the mantle at which the velocities of seismic waves changed abruptly. This region is called the Mohorovičić Discontinuity (Moho).


Epicenter
Mohorovičić discontinuity (Moho)
P S L
Crust
Inner core
Outer core
P L
Shadow zone
Mantle
Shadow zone
P

VI. Metamorphic Rocks.

A. Introduction.

1. Metamorphic rocks are caused by the forces that change the shape of the earth's crust.

2. Crustal rocks are warped, folded, and compressed by tremendous pressure and heat. The movements may be due to adjustments of the earth's crust to allow for:

   a. Igneous intrusion.

   b. Increasing weight of accumulating sediments.

   c. Earth movements due to various other causes.

3. Heat and pressure cause both chemical and physical changes in rock forming minerals.

   a. Heat along contact areas of intrusions may cause recrystallization.

   b. Folding of strata may tear, stretch, or smash minerals.

   c. Gases and liquids escaping from the magma of intrusions may penetrate the surrounding rocks.

   d. Chemical reactions between existing minerals may produce large crystals of garnet or other metamorphic minerals.

   e. Deeply buried rocks are also altered by heat from the depths of the earth.

4. The most noticeable effect of metamorphism on rock is foliation.

   a. In foliated rocks the minerals are drawn out, flattened, and arranged in parallel layers.

      1) Rocks that contain mica or iron magnesium minerals tend to show foliation.
      2) Foliated rocks tend to split parallel to the banding, while unfoliated rocks fracture without definite pattern.

B. Simpler Metamorphic Rocks.

1. Most of the simpler metamorphic rocks are formed directly from sedimentary rocks. Changes are due largely to recrystallization of existing minerals in the rock. Very few new minerals are formed.

2. Slate - formed from shale. Is usually very fine grained, and shows slaty cleavage.

3. Marble - recrystallized limestone; the crystals are enlarged, and organic materials are driven off causing a lightening of color.

4. Quartzite - compacted quartz sandstone-- forms the bulk of many hills and mountains because it is very hard and chemically resistant.

5. Serpentine - metamorphosed Pyroxine, Peridotite and Dunite.

C. More Complex Metamorphic Rocks.

1. Phyllites and Schists.

a. Phyllites - formed from shale under greater pressure than that under which slate forms. Shows higher luster than slate and may be silky in luster due to the presence of fine grains of mica.

b. Schists - formed under greater pressure from shale. Coarser, showing definite foliation, splits fairly easily along bends. Classified according to most prominent mineral:

Mica Schist	Chlorite Schist
Hornblende Schist	Quartz Schist

2. Gneiss - very highly metamorphosed from Granite Schists, and other rocks. Normally coarse grained and banded. Classified according to structure or origin:

Mica Gneiss	Hornblende Gneiss
Granite Gneiss	Injection Gneiss

3. The series formed as heat and pressure increase proceeds from shale ⟶ slate ⟶ phyllite ⟶ schist ⟶ gneiss ⟶ migmatite ⟶ magma.

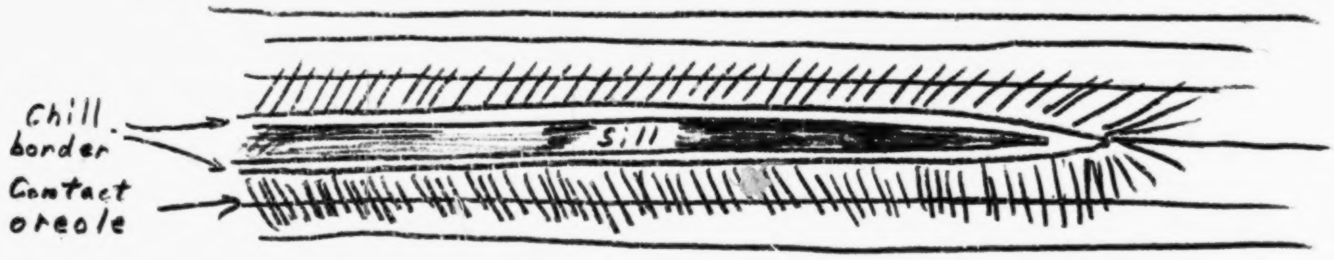
a. As the heat and pressure approach the melting point of the rock, the minerals begin to separate into a mass that is rather plastic. The cooled product at this stage is called a migmatite.

b. Further heating will result in melting and magma formation. This hot liquid magma may melt its way into existing rocks, converting the melted rocks into a granite-like mixture and metamorphosing the surrounding rocks.

D. Metamorphic rocks fall into two broad categories.

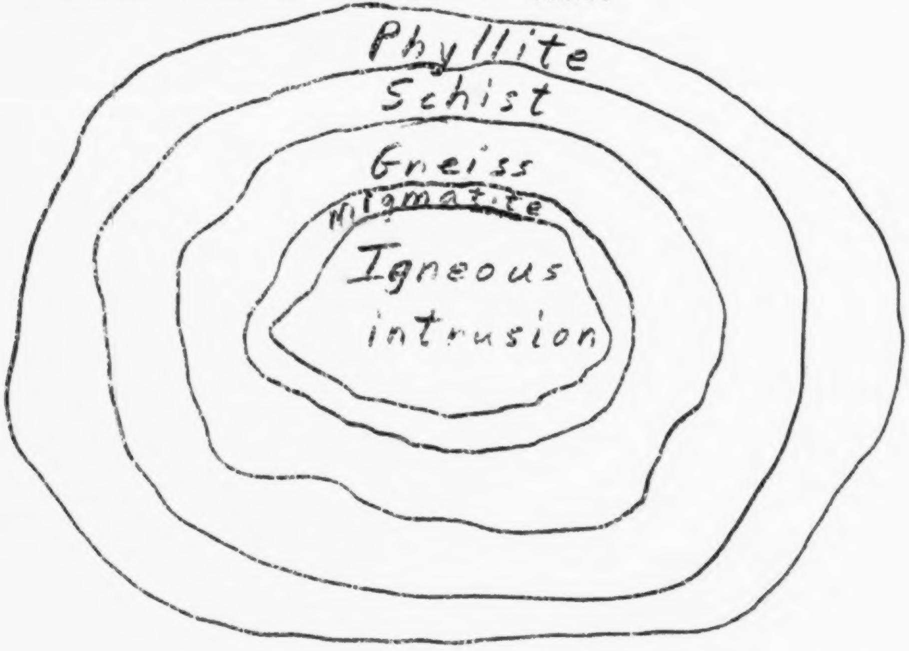
1. Contact metamorphic rocks - are formed by the local metamorphism of intruding dikes, or sills, or beneath lava flows.

    a. This type of metamorphism results in contact oreoles around dikes and sills or metamorphic floors under lava flows.


Chill border
Contact oreole
sill

    b. The removal of heat from the igneous bodies in contact with the surrounding rock usually creates a chill border in the igneous rock.

2. Regionally Metamorphosed Rock - The intrusion of a Batholith, a Laccolith, a stock, or some other large magma body usually results in metamorphism of the rocks in the region surrounding the body. The degree of metamorphism generally decreases with increasing distance from the center of heat.


Phyllite
Schist
Gneiss
Migmatite
Igneous intrusion

LESSON 26, Introduction

MOUNTAINS

Objectives:

1. To develop an understanding of the basic processes involved in mountain building.
2. To create a concept of the combined effects of time and erosion on a mountain range.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 16.
2. FOCUS ON EARTH SCIENCE, Chapter 17.
3. INVESTIGATING THE EARTH, Chapters 14, 15, and 16.

Special References:
Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 30.
Gilluly, et al. PRINCIPLES OF GEOLOGY (Freeman Publishing Company, San Francisco), Chapter 20.
Shelton. GEOLOGY ILLUSTRATED (Freeman Publishing Company, San Francisco), Chapter 34.
Wyckoff. ROCKS, TIME AND LANDFORMS (Harper & Row Publishers, Inc., New York), Chapter 6.

Activities:

Field trips through the mountains.

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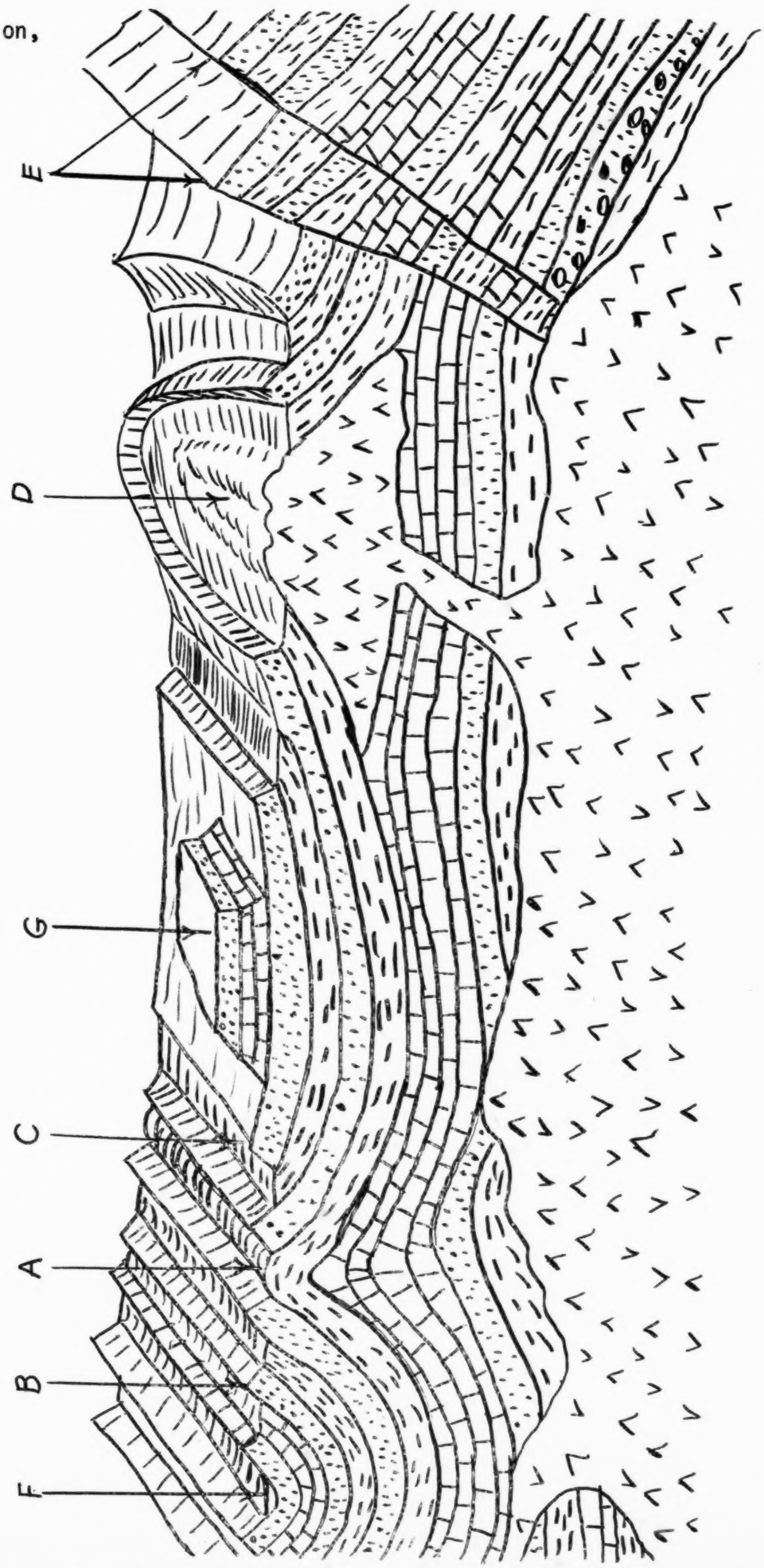
For the following questions, refer to the cross section which follows. Blacken in the appropriate answer.

1. The letter F represents (a) anticline, (b) syncline, (c) fault, (d) igneous intrusion.
2. The letter B represents (a) hogback, (b) cuesta, (c) butte, (d) mesa, (e) peneplain.
3. The letter A represents (a) anticline,(b) syncline, (c) fault, (d) monadnock, (e) mesa.
4. The letter C represents (a) hogback, (b) cuesta, (c) fault, (d) anticline, (e) syncline.
5. The letter D represents (a) fault block mountains, (b) folded mountains, (c) dome mountains, (d) volcanic mountains.
6. D was formed by an igneous intrusion called a (a) batholith, (b) stock, (c) sill, (d) laccolith, (e) dike.
7. The letter E represents (a) fault block mountains, (b) folded mountains, (c) dome mountains, (d) volcanic mountains.

8. Letter G represents (a) monadnock, (b) cuesta, (c) hogback, (d) mesa, (e) anticline.
9. The area between F and A is typical of (a) fault block mountains, (b) folded mountains, (c) dome mountains, (d) volcanic mountains.
10. The entire area of the cross section might be referred to as (a) ridge and valley, (b) eroded mountains, (c) complex mountains, (d) a volcanic area, (e) a national disaster.


F
B
A
C
G
D
E

LESSON 26

MOUNTAINS

I. Introduction

Mountains are the highest solid part of the earth. No other landforms display such varied and beautiful scenery.

A. Mountains are not as steep as they appear.

1. The average steepness (slope) of mountains is about 20°.

2. Mountains give the appearance of steepness because the slope is not continuous but is broken by step-like areas that have very steep slopes.

B. True mountains have a complicated relief of over 2,000 feet.

1. Many areas of rough surface which are locally called "mountains" are really only hills. (Examples: Kings Mountain, Crowders Mountain, etc.)

2. The highest mountain in the world is Mt. Everest in the Asian Himalayas (elevation 29,028 feet).

3. The deepest ocean trench is the Marianas Trench in the Pacific (elevation is about 35,000 feet below sea level).

4. The total relief of the earth is then about 12 miles.

C. Definitions of terms used to describe mountains:

1. Peak - single, more or less, isolated summit.

2. Ridge - an elongate crest or a linear series of crests.

3. Range - continuous group of peaks and valleys.

4. Chain - group of ridges that run in parallel patterns.

5. System - group of ranges similar in form and structure.

6. Cordillera - a belt of mountain systems of great extent.

II. Cordillera are generally near and parallel to the borders of continents in regions of crustal weakness. There are four great cordilleran regions which include almost all of the great mountains in the world.

A. The North American Cordillera.

B. The Southern European Cordillera.

C. The Asiatic Cordillera.

D. The South American-Antarctica Cordillera.

III. Mountains pass through stages of development due to erosional forces.

   A. During youth, mountains are still growing.
   (NOTE: This is a very slow process, requiring long periods of time and accompanied by occasional earthquakes. Either the Pacific Coast Ranges or the Aleutian Mountain Range may be cited as an example.)

   B. Erosion alters surface as it is built up.

      1. Results in high, steep mountains with sharp peaks and deep narrow valleys.

      2. Young mountains often rise well above the snow line and thus support glaciers during the entire year.

      3. Mountain streams are vigorous and cut narrow and deep ravines or V-shaped gorges. (There are often numerous waterfalls and/or rapids.)

   C. In young fault-block mountains, fault scarps are prominent. The scarps show notches where valleys were cut off by movement along the fault.

IV. Mature Mountain Features.

   A. In maturity, mountain growth has stopped.

   B. Rugged scenery has been worn down to rounded summits.

   C. Gentler slopes are fringed by talus, covered with sand or soil.

   D. In lower and middle latitudes, timber usually reaches summits.

   E. Glaciers are rare except in high latitudes.

   F. Earthquakes seldom originate in mature mountains.

   G. Streams have also matured.

      1. Flow is slower.

      2. Valleys are wider and have gentler slopes.

      3. Stream divides have become rounded.

      4. Some streams are older than the mountains themselves.

         a. Established before uplift of mountains.

         b. Streams cut deep, keeping pace with the rise.

         c. Water gaps and wind gaps develop.

H. The Appalachians (ridge and valley) are good examples of folded anticlinal and synclinal mountains that are mature.

V. There is no clear line of division between maturity and old age.

A. Mountains are worn down almost level, the final surface being a peneplain with low relief.

B. Rivers are very slow with few tributaries and low banks.

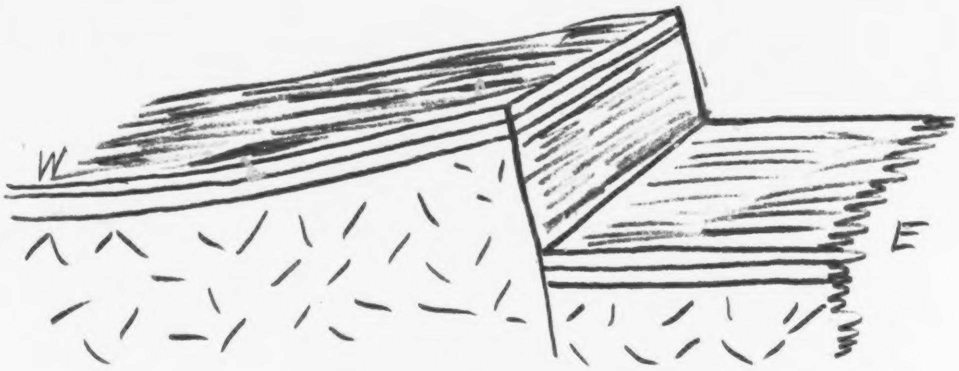
C. Bedrock is covered with a deep layer of weathered rock and soil deposits.

Examples: North Carolina Piedmont, Uwharrie Mountains.

VI. Mountains of Diastrophic Origin.

Many mountain ranges are the result of diastrophic processes. They fall into two main groups.

A. Block mountains - result from faulting, known as block mountains due to basic form, usually vary greatly in form due to erosion. Example: Sierra Nevada (block 400 miles long and 50-80 miles wide. Slopes west. Fault scarp faces east rising 2 miles high in places.)



B. Folded mountains - result from folding of sedimentary or lava beds.

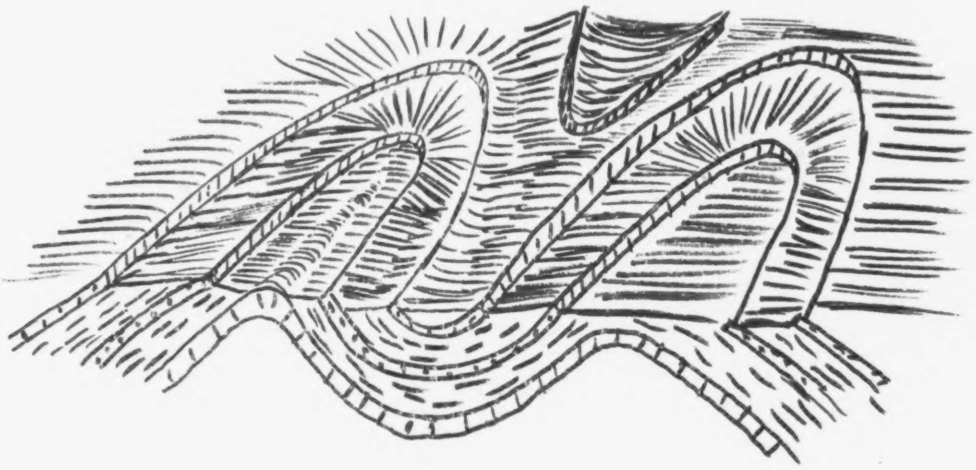
1. May be anticlinal or synclinal or resistant beds may be left by erosion as synclinal or monoclinal ridges.

2. The newer Appalachians in Pennsylvania and Virginia are made of very old sedimentary rocks (also the Ozarks).

  a. Beds were folded and uplifted several times at widely separated intervals resulting in long ridges.

  b. The tops of these ridges are even respresenting the remains of an erosional peneplain.

  c. Cigar-shaped mountains, zig-zag ridges, and canoe-like synclinal ridges are typical of this region.



VII. Volcanic cone and dome mountains result from volcanism. They occur as two types:

A. Volcanic cones - Example: Lassen Peak in California and Mount Vesuvius in Italy.

1. Formed by the gradual building up of their slopes.

  a. Occur mainly by accumulation of volcanic fragments and lava flows.

  b. The great volcanic mountains of Hawaii result from lava flows. They rise some 30,000 feet from the ocean floor, and their circumference at sea level is about 100 miles.

  c. When lava solidifies in main vents and pipes instead of flowing out, the volcano becomes extinct.

1) Later erosion of the less resistant cone leaves upstanding plugs or peaks.
2) These may rise as much as 2,000 feet above the surrounding countryside. In Arizona and New Mexico there are 150 plugs marking the sites of former volcanoes. (Examples: Ship Rock, Devil's Tower.)
3) Entire mountain ranges have formed from volcanic deposits.

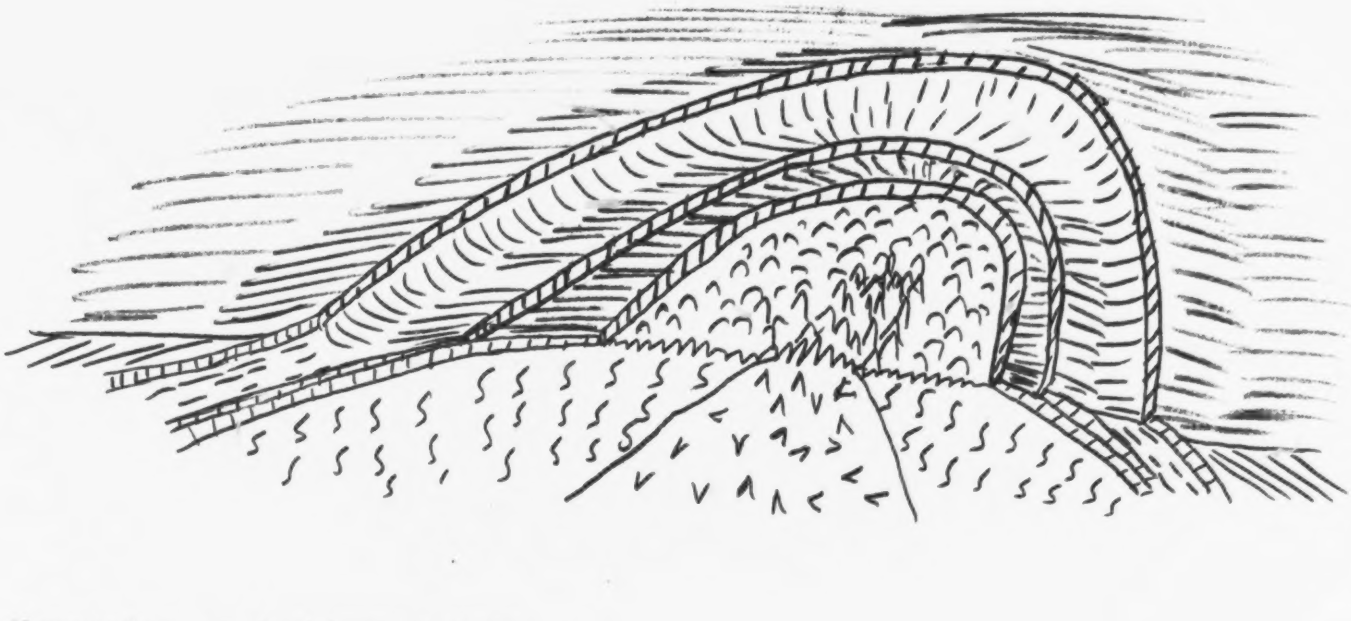
   a) The Aleutian Islands - volcanic range now rising along the Alaskan coast.
   b) Hawaiian Islands - also developing range.

B. Dome mountains - sedimentary beds may be uplifted into broad dome mountains either by intrusive laccoliths or batholiths. All dome mountains have the following features:

1. An underlying central core of resistant igneous rock.

2. Erosion of the overlying sedimentary strata results in circular ridges around the central core.

3. Irregular mountainous topography results from erosion.



VIII. Mountains of Combined Origin.

A. Result from a combination of mountain-building forces and are called complex mountains.

B. Formed by a combination of two or more of the following processes.

1. Folding.

2. Faulting.

3. Volcanic eruption.

4. Igneous intrusion and dome formation.

C. The Appalachians (particularly the Blue Ridge Mountains) are good examples of complex mountains.

IX. Mountains of Erosional Origin.

A. Some landforms called mountains are actually deeply eroded or dissected (cut-up) plateaus. Example: Catskill Mountains in New York.

B. Buttes and mesas are isolated remnants of horizontal, undisturbed strata.

C. Monadnocks are isolated hills or mountains of resistant rocks rising above the general level of a peneplain (usually igneous or metamorphic rock). Examples: Hanging Rock, Pilot Mountain.

LESSON 27, Introduction

PLAINS AND PLATEAUS

Objectives:

1. To gain an understanding of types of plains and plateaus and their relation to the forces of formation.
2. To develop the relationship between the history of an area or landform and the surface that results.

References:

THE EARTH-SPACE SCIENCES, Chapter 16.

Special References:
Strahler, PHYSICAL GEOGRAPHY (John Wiley & Sons, New York), Chapter 29.
Shelton, GEOLOGY ILLUSTRATED (W. H. Freeman & Company, San Francisco), Chapter 15.
Wyckoff, ROCK, TIME, AND LANDFORMS (Harper & Row Publishers, Inc., New York), Chapter 8.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 29.

Activities:

1. Field Trips

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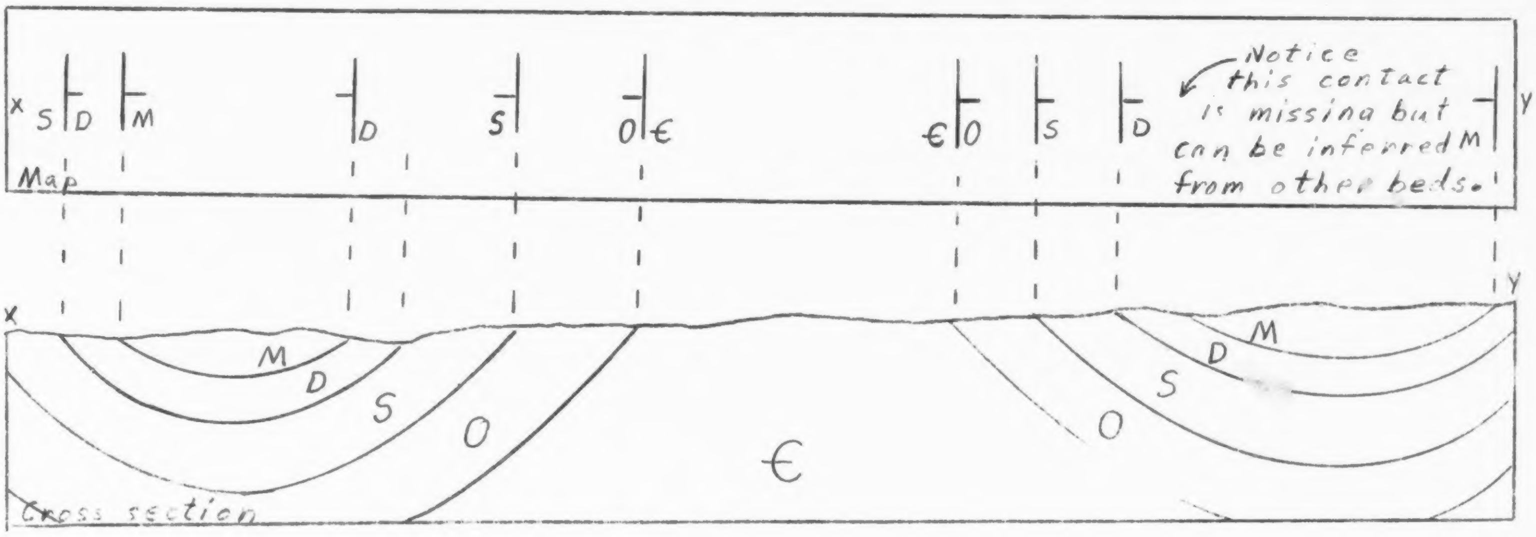
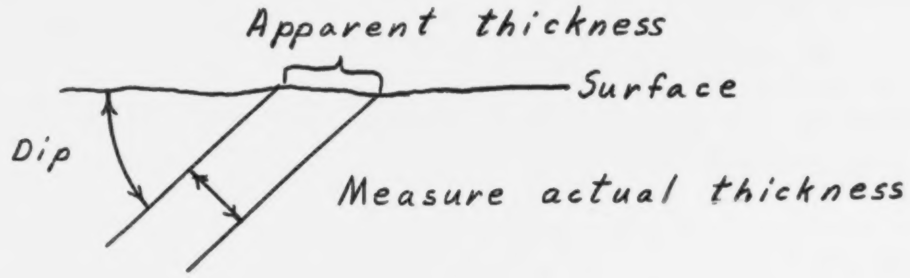
GEOLOGIC MAPPING EXERCISE I

Introduction: Previously you have drawn profiles of topographic maps. This exercise involves projecting the structure of rocks below the surface on the basis of their surface relationship, strike and dip, and apparent thickness. The section below has been completed in order that you might see the relationship between the map and the cross section.



Notice this contact is missing but can be inferred from other beds.

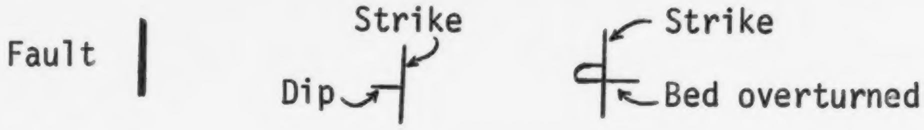
The problem of determining the true thickness of a bed can be solved rather simply. Remember that when a bed dips vertically, the width of the bed exposed at the surface is the true thickness.


Apparent thickness
Surface
Dip
Measure actual thickness

Remember:

1. Unless there is evidence to the contrary, all folds are smooth bends.
2. Attitude symbols are drawn on contacts.
3. All bed thicknesses in this exercise remain constant.
4. All symbols are not shown.
5. In the following two exercises, D is three times as thick as C and C is two and one half times as thick as O.

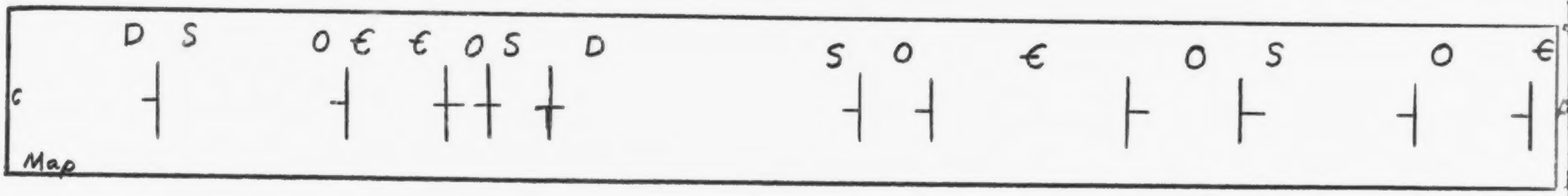
Symbols:

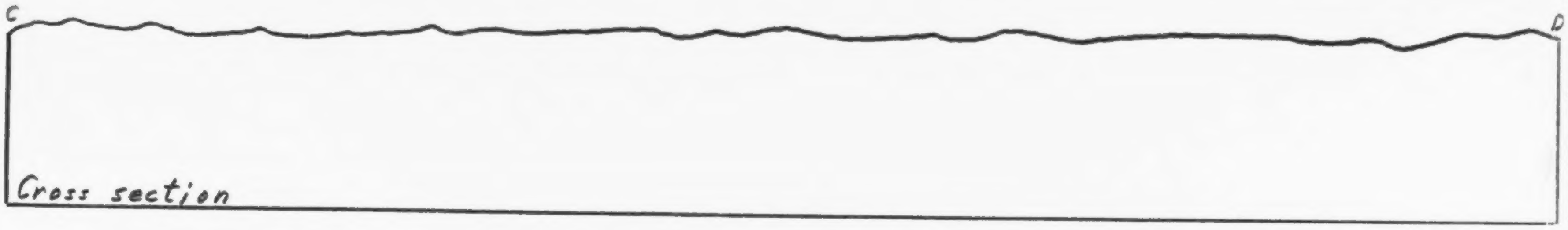

Fault
Strike
Dip
Strike
Bed overturned

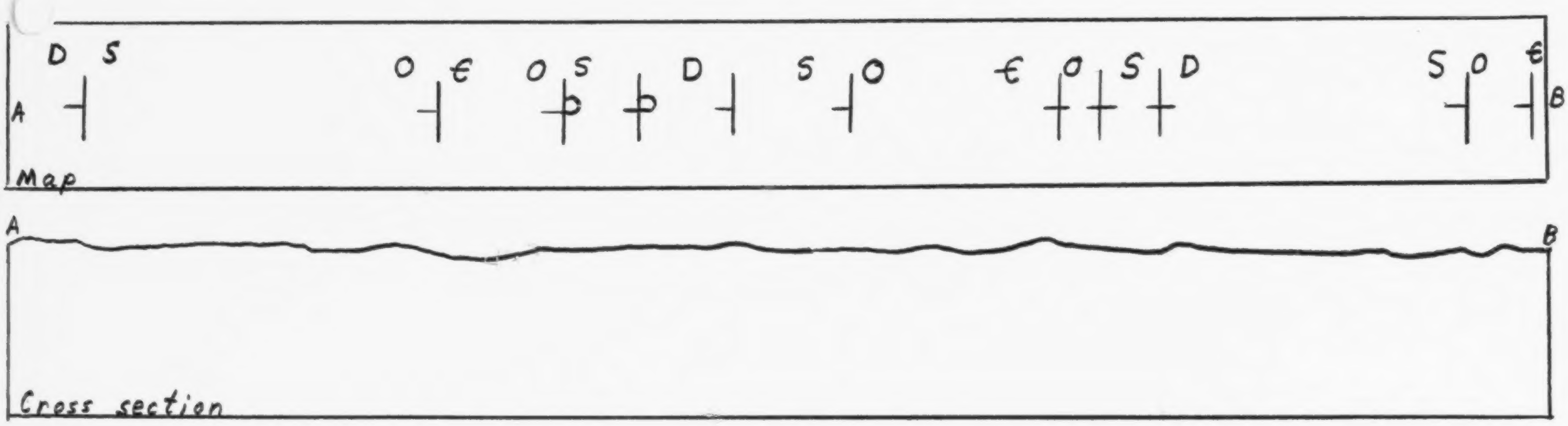
D - Devonian
S - Silurian
O - Ordovician
C - Cambrian
PE - Precambrian

Tr - Triassic
P - Permian
Cp - Pennsylvanian
Cm - Mississippian

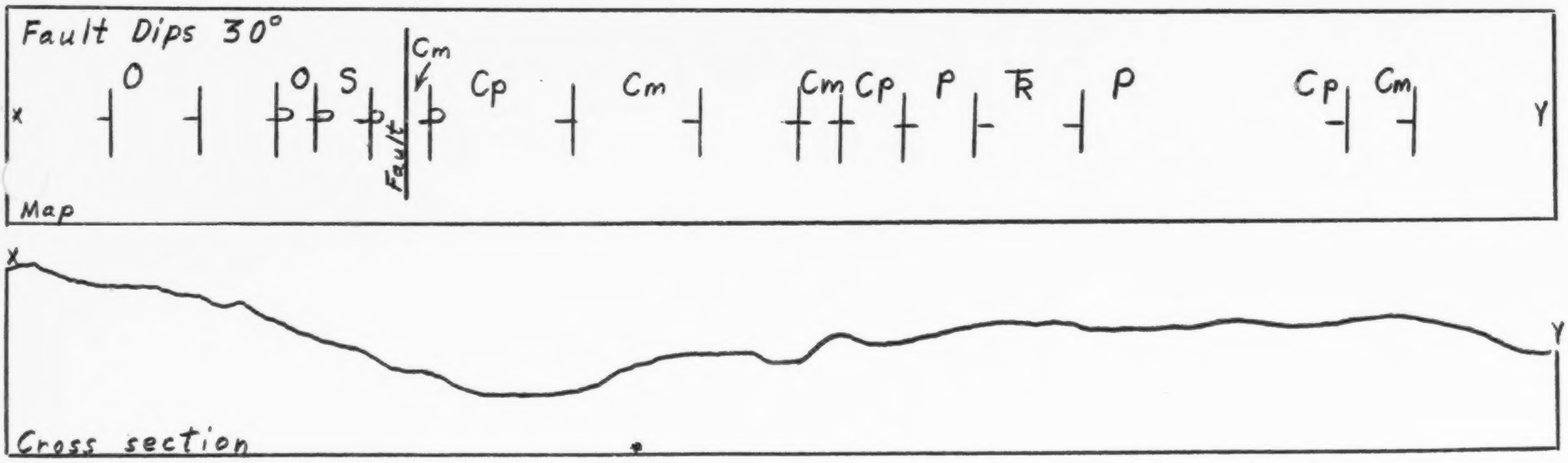
When you complete the cross section, color the beds and label each with the appropriate symbol.


D S
O € € O S
D
S O
€
O S
O €
C
D
Map


C
D
Cross section


D
S
O
Є
O
S
D
S
O
Є
O
S
D
S
O
Є
A
B
Map
A
B
Cross section

If you found the previous two interesting and enjoyable, try the one below.


Fault Dips 30°
X
O
O
S
Cm
Fault
Cp
Cm
Cm
Cp
P
R̄
P
Cp
Cm
Y
Map
X
Y
Cross section

LESSON 27

PLAINS AND PLATEAUS

I. Origin of Plains and Plateaus.

Plains and plateaus are generally composed of layers of rock in horizontal position.

A. Plains and plateaus are the result of deposition following erosion.

1. However, many are considered constructional landforms because they have emerged due to diastrophic action.

2. Plains and plateaus are exposed when flat-lying beds covered by seas or lakes are then up-lifted or uncovered by lowering of the water level.

B. A slight lowering of the water level or rising of the land exposes broad flat rock beds called coastal plains, interior plains, or lake plains, depending on the conditions of formation.

C. Constructional volcanism may result in lava plains and plateaus.

D. Some plains are the direct result of destructional agents.

1. Alluvial plains - formed by the deposition of material from rivers and streams.

2. Outwash plains - formed by deposition of material by streams and rivers flowing out of glaciers.

3. Till plains - masses of material deposited by a glacier.

II. Coastal Plains are composed of fragments eroded from rocks along the shore by ocean waves or carried into the ocean by rivers. Wave action spreads out the debris into a smooth flat surface.

A. The surface extends seaward often for hundreds of miles under the water forming the continental shelf.

B. On emergence all or part of this shelf becomes a coastal plain.

1. Coastal plains vary widely in width and in their surface features because of:

a. The structure of the rock beds.

b. The nature and degree of uplift.

c. The type of old land on which the coastal plain rests.

2. Beds in a typical coastal plain:

a. Probably flooded and drained several times due to changes in sea level.

b. Periods of erosion would have altered with periods of deposition.

c. Uplift may have been simple or included warping into low domes and basins.

d. The old land surface may have been flat or irregular.

III. Example: The Atlantic Coastal Plain.

A. The Atlantic Coastal Plain and its extension, the Gulf Coastal Plain, extend from New York through Florida and Texas to Mexico.

1. Deposits consist of hundreds of feet of loose beds of sand lime, and clay.

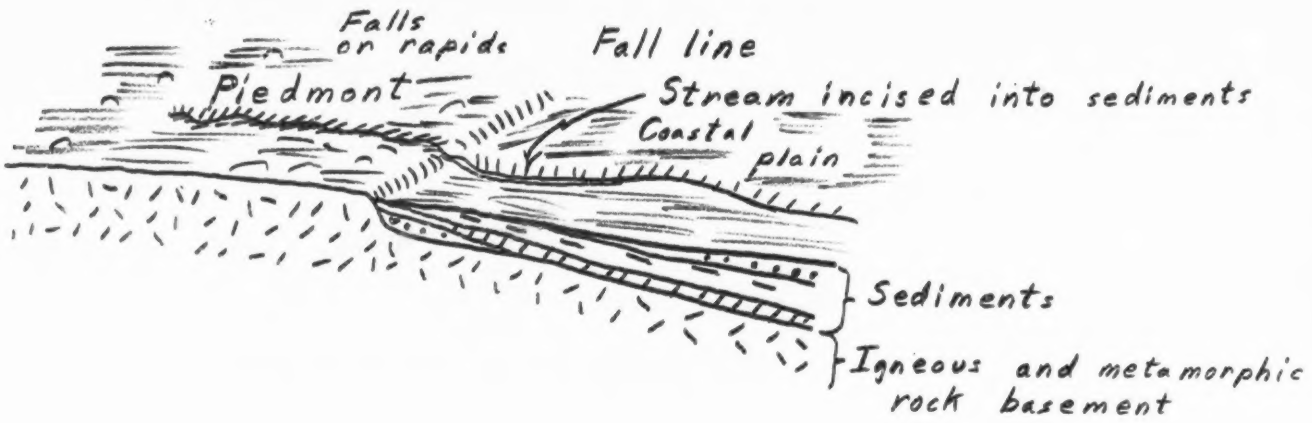
2. The old land is ancient metamorphic rock like that which also forms the Appalachian Mountains.

3. When the beds were laid down, the shoreline was at the edge of the piedmont upland.

a. This joining of sediments to the old land is called the fall line.

b. Waterfalls mark the change in slope of the streams that pass from the old land down onto the plain.

(1) Many major cities are located on the fall line. Trenton, N. J.; Philadelphia, Pa.; Baltimore, Md.; Raleigh, N. C.
(2) These cities grew up because of the waterfall power available at the fall line.


Falls or rapids
Fall line
Piedmont
Stream incised into sediments
Coastal plain
Sediments
Igneous and metamorphic rock basement

B. History of the Coastal Plain.

1. Deposition of sediments.

2. Area was greatly uplifted. Rivers began to cut valleys across the new plain.

3. A great deal of the area now under water was exposed.

4. The shoreline advanced and retreated periodically.

5. The latest submergence gave the shoreline its present position.

   a. The submergence drowned many river valleys forming the harbors, bays, and sounds on the east coast.

   b. Outcrops of gently dipping beds that can be traced from Georgia to the ocean bottom off New England.

6. The topography is typical of land that was recently part of the sea floor.

   a. Broad areas of flat land are broken only by occasional groups of low hills.

   b. In the north, some of these hilly regions are due to glacial deposits.

   c. In the south, they mark outcrops of resistant rock.

   d. The plain shows features common in areas of wind and sea action.

      1) Cliffs.
      2) Sand bars and dunes.
      3) Marshes and swamps (Everglades occupy 6,000 of the 7,000 square miles in southern Florida.)

   e. The rivers of the Atlantic Coastal Plain do not form deltas because the waves and currents of the ocean carry off the sediment and distribute it along the coast and on the continental shelf.

IV. Interior Marine Plains.

A. Interiors are vast inland areas that were once covered by shallow water. They were exposed by the ocean's retreat.

B. The area is usually very flat with a few low domes.

   C. There are only a few very slowly flowing and meandering streams.

      1. Progressing erosion results in an area of low rolling hills.

      2. The interior plains of the United States are a good example.

V. Lacustrine (lake) Plains.

   A. Formed by emergence of a lake floor.

      1. Occasionally due to uplift of the lake sediments.

      2. More often the emergence results from the drainage of large lakes.

   B. Glacial Lake Agassiz - formed when northern drainage streams were blocked by glacial ice.

      1. Covered a large area in Canada and the states of Minnesota and North Dakota - area 100,000 square miles.

      2. Drained when glaciers melted - now forms flat plain of rich black soil (major wheat farming region).

   C. Lake Bonneyville (Utah).

      1. Once as large as Lake Huron.

      2. Evaporation has reduced it to present Great Salt Lake leaving lacustrine plains.

      3. Former shorelines can be identified in valleys between mountain ranges that were once islands.

VI. Plateaus.

   A. Elevation.

      1. Elevations of most plateaus of the world exceed 2,000 feet.

      2. Land is not classified as a plain solely on the basis of elevation.

         a. The relative elevation of a region is more important than its actual elevation.

         b. The relief is the most important basis of classification.

            1) A plateau has high relief.
            2) A plain has low relief.

3. A plateau forms an escarpment at least on one side.

   a. An escarpment marks the change to lower elevation.

   b. The escarpment is normally deeply carved by streams.

B. Origins.

1. True plateaus may be classified according to their origin. Most plateaus are the result of diastrophism.

2. Faulting.

   a. The Colorado Plateau (130,000 mi^2) resulted from broad uplift followed by vertical faulting.

   b. Repeated uplift and erosion has resulted in the formation of deep canyons (Example: Grand Canyon). The plateau elevation at the Grand Canyon is between 7,500 and 9,300 feet above mean sea level.

3. Warping.

   a. The Appalachian Plateau was raised slowly without much faulting. It is called a warped plateau because of its original blister-like raised nature.

   b. The Appalachian Plateau is a typical mature plateau cut by many streams.

      1) These streams have formed round top hills and gently sloping valleys.
      2) The hills are called the Allegheny Mountains.
      3) The tops of the ridges form a nearly level skyline indicating the original flat nature.

4. Volcanic activity.

   a. The Columbia and Snake River Plateau is one of the largest lava flows in the world.

   b. Basaltic lava flows, spreading from fissures, covered at least 200,000 mi^2 over an old area of mountains.

   c. The greatest thickness is at least 5,000 feet. The Blue and Elkhorn Mountains were surrounded and partly buried by the lava.

   d. In some places the lava beds were raised into low anticlinal folds creating long ridges.

   e. The Snake River Canyon cut in this plateau is as deep as the Grand Canyon; however, it lacks the contrasting colors of the sedimentary beds. The steep walls of the river gorges in the plateau are due to columnar jointing.

VII. Types of Plateaus.

A. Intermountain plateaus (between mountains).

   1. The name applies to high, flat surfaces between mountains.

   2. Intermountain plateaus include the Columbia Lava Plateau and the Great Plains.

B. Piedmont plateaus (mountain foot).

   1. Bounded on one side by mountains and on the other side by lowlands, seas, or plains.

   2. Examples include the Colorado Plateau and the Appalachian Plateau (Cumberland Plateau and Allegheny Plateau).

C. Continental plateaus rise abruptly from adjacent lowlands or from the sea. They are not usually rimmed by mountains, and they often form regular shorelines with few indentations. (Example: Continent of Africa)

D. Ice plateaus.

   1. Greenland and Antarctica are both almost entirely covered by relatively flat-topped ice caps (continental glaciers).

      a. Greenland is best known. The area is about 666,000 square miles. Ice cap rises to about 10,000 feet above sea level.

      b. Antarctic ice sheet covers about 5,000,000 square miles with a maximum thickness of about 14,000 feet.

   2. These ice sheets are like the continental glaciers which covered North America and Europe during the most recent glacial period.

   3. The outer edge of the glacier ends in steep cliffs of ice which continue to break off and drop into the sea forming icebergs.

IX. Life History of Plateaus.

A. The appearance of a plateau at different stages of erosion depends on climatic conditions and the type of rock that underlies the plateau.

B. A young plateau in a semiarid region like the Colorado Plateau shows striking scenery. In less arid regions, young plateaus show rounder surfaces and gentler slopes, with soil covering and some talus. Streams are few and cut deeply into the rock.

C. Mature plateaus are generally called mountains, since they are thoroughly dissected by streams.

   1. The Catskill "Mountains" are actually a mature plateau.

   2. Summits are relatively flat-topped and there are terraces or benches along the sides which reveal the generally horizontal structure of the original rocks.

D. Old age plateaus are worn almost level leaving standing only remnants of the original plateau (mesas, buttes, etc.).

   1. In arid regions, these are steep walled with flat surfaces.

   2. In humid regions, these remnants are more rounded.

LESSON 28, Introduction

THEORIES OF CRUSTAL MOVEMENT

Objectives:

1. To survey the theories applied to explain diastrophic movement.
2. To develop a suitable combination of theories that will explain diastrophic phenomena in general terms.

References:

1. THE EARTH-SPACE SCIENCES, Chapters 13 and 20.
2. FOCUS ON EARTH SCIENCE, Chapter 17.
3. INVESTIGATING THE EARTH, Chapters 14 and 16.

Special References:
Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 12.
Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapters 24, 27, 28, 29, 30, and 31.
Gilluly, et al. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company, San Francisco), Chapters 19 and 20.

Activities:

1. Investigating Earthquakes
   ESCP 14-5 Text 318
   Teacher's Manual 388-389

2. Continental Drift: Make cut-outs of the continents and try to fit them together. What reasons can you propose for a lack of perfect fit?

GEOLOGIC MAPPING EXERCISE II

Geologists map the structure of a region using many techniques. One of the most reliable and most often used techniques is reconstruction from notes made in the field. The exercise that follows develops the structure in an area of Wyoming known as Oil Creek. The geologist noted his observations (they are condensed here) at 54 different locations in the area. Each location is marked on the base map along with the creeks and road locations. Your task is to compile the locations on the map and draw the structure. Your finished map should look like any other geologic map. To help you get started: the contacts inferred from stations 1 and 2 have been drawn in and labeled.

NOTE: This lab exercise is too involved for all but the most advanced eighth grade students. It is offered here primarily to allow you to experience the type of problems which confront geologists as they unravel problems in the field.

HINTS: Before you start, read the Geological Survey Pamphlet Geologic Maps, Portraits of the Earth and Principles of Geology, Chapter 6. Do the lab in pencil and mark the age of the rocks on each side of every contact. When you begin to see a trend, rough it in; you can always erase mistakes. When you have all the contacts and faults drawn in, you can remove many of the age symbols and use a color or color pattern in their places.

OIL CREEK, WYOMING REGION

Field Notes:

Sta. 1 - Ku (Upper Cretaceous) str. N30W, dip 10 NE. Contact of Ku with horizontal Tf (Early Tertiary fan deposit) observed at base of bluff ½ mi. north and south of Oil Creek paralleling stream course.

Sta. 2 - Contact Ku-Tf trending N30W at base of bluffs. Similar contact seen south of Oil Creek trending in SE direction. Both contacts continue to limits of map area.

Sta. 3 - Ku-Kl contact, beds str. N32W, dip 40 NE. Contact curves toward N-S trend within 2 miles S of this station.

Sta. 4 - Kl (Lower Cretaceous) - Js (Jurassic) contact; beds str. N30W, dip 35 NE. Contact parallels Kl-Ku contact to north and south.

Sta. 5 - Js overlain by horizontal Tf; contact trends N28W for 1¼ miles. Tf capping is seen to be continuous for about 1½ mi. to SW, W, and NW.

Sta. 6 - Js-Tr (Triassic) contact; beds str. N20W, dip 30E.

Sta. 7 - Flat-lying Tf roughly circular capping 3/4 mi. in diameter overlaps Js on N, NE, SE, S, SW, and W; overlaps Tr on NW.

Sta. 8 - Js-Kl contact; beds str. N60E, dip 6SE.

Sta. 9 - Kl-Ku contact; beds str. N70W, dip 10 SW.

Sta. 10 - Kl-Ku contact; beds str. N40W, dip 13 SW.

Sta. 11 - Kl-Js contact; beds str. N36W, dip 18 SW. At outcrop 5/8 mi. N33W from Sta. 11 this contact is covered by horizontal Tf.

Sta. 12 - Js-Tr contact; beds str. N30W, dip 15 SW. Tr exposed continually along Canyon Creek to Sta. 6. Tf overlaps Js-Tr contact ¼ mi. north.

Sta. 13 - Edge of Tf capping on Js. Js-Kl contact ¼ mi. W.

Sta. 14 - Kl-Ku contact; beds str. N20W, dip 11W.

Sta. 15 - Ku-Kl contact; beds str. N28W, dip 65 NE.

Sta. 16 - Kl-Js contact; beds str. and dip same as Sta. 15. Kl 900 ft. thick in this vicinity.

Sta. 17 - Kl-Js contact; beds str. N15W, dip 9 SW.

Sta. 18 - Western extremity of roughly elliptical Tf capping just overlaps Kl-Js contact at this station. Long axis of capping trends N60E approx. 3/4 mi. long, ½ mi. wide, underlain by Js everywhere except at Sta. 18.

Sta. 19 - Kl-Js contact; beds str. N25E, dip 6 NW.

Sta. 20 - Kl-Js contact; beds str. N70W, dip 8 N.

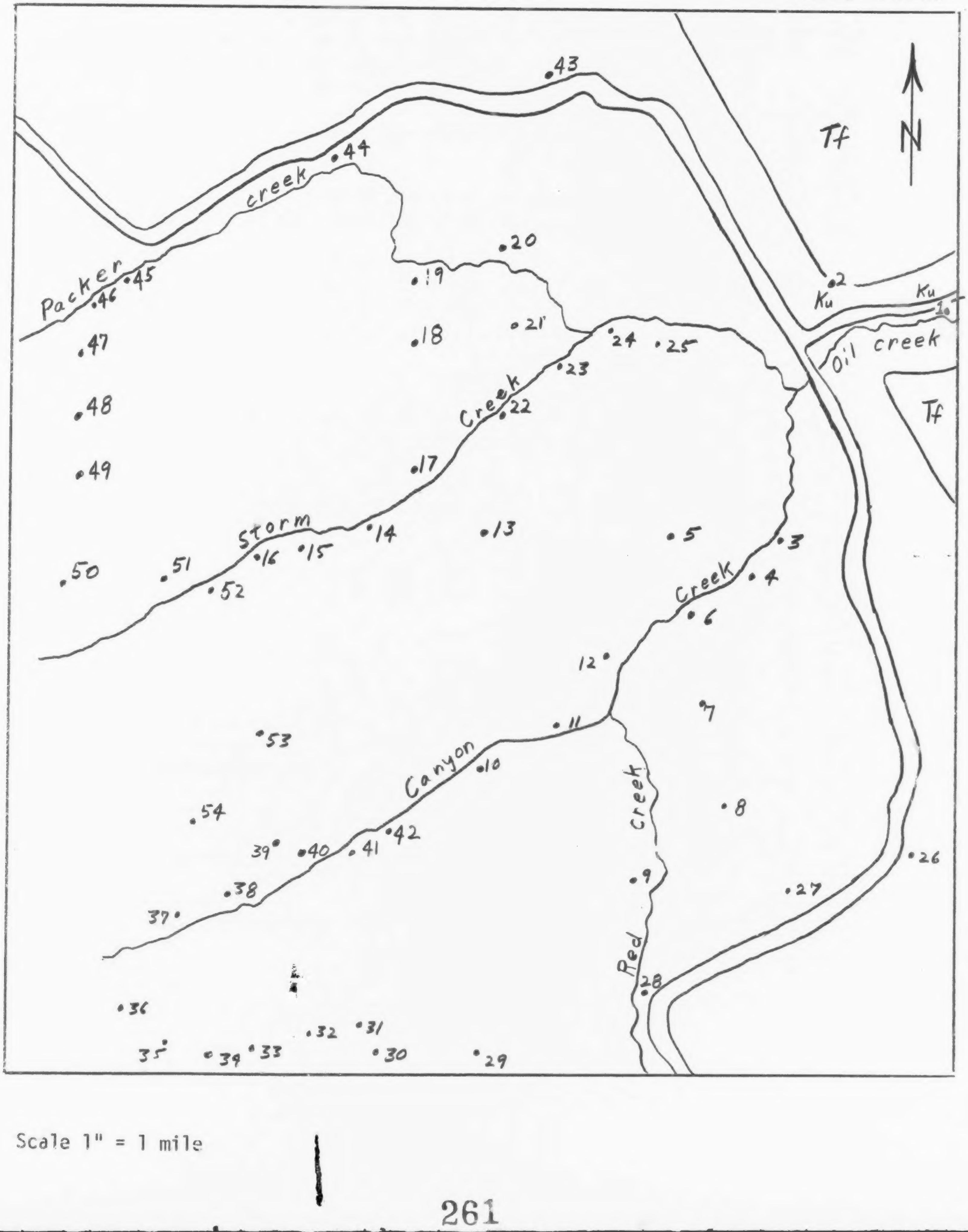
Sta. 21 - East edge of Tf capping, on Js.

Sta. 22 - Js-Tr contact; beds str. N-S, dip 6W. Tf covers contact ¼ mi. S.
Sta. 23 - Tr-Js contact; beds str. N35W, dip 10 NE.
Sta. 24 - Js-Kl contact; beds str. N30W, dip 25 NE. Tf caps Js ½ mi. S. Js-Kl contact not covered between Sta. 24 and Sta. 4.
Sta. 25 - Kl-Ku contact; beds str. N30W, dip 36 NE.
Sta. 26 - Ku str. N15E, dip 10 SE.
Sta. 27 - Ku-Kl contact; beds str. N56E, dip 5 SE.
Sta. 28 - Ku str. N75W, dip 8 SW.
Sta. 29 - Ku str. N15E, dip 35 SE.
Sta. 30 - Ku-Kl contact; beds str. N-S, dip 50 E.
Sta. 31 - Kl-Js contact; beds str. N-S, dip 50 E. Kl in this vicinity only 100' thick.
Sta. 32 - Js-Tr contact; beds str. N-S, dip 65 E.
Sta. 33 - Fault plane, str. N28W, dip 5 SW. M (Mississippian) on Tr.
Sta. 34 - M-D (Devonian) contact, beds str. N26W, dip 70 SW, overturned.
Sta. 35 - D-€ (Cambrian) contact, str. and dip same as Sta. 34. Disconformity at contact.
Sta. 36 - €-pre€ (Precambrian) contact, str. and dip same as at Sta. 34. Slightly unconformable contact.
Sta. 37 - Tear fault trending N68E D&M along south side of fault; pre€ along north side D&M str. N10E, dip 80 W, overturned.
Sta. 38 - P (Permian) & Tr (Str. N-S, dip 80 E) appear to underlie C, D, and M along N bank of creek; fault plane strikes N68E, vertical. D&M str. N20E, dip 80 W, overturned.
Sta. 39 - Fault plane, str. N26W, dip 6 SW, M on Tr.
Sta. 40 - Tr-Js contact, beds str. N10W, dip 70 E.
Sta. 41 - Js-Kl contact, beds str. N2W, dip 52 E.
Sta. 42 - Kl-Ku contact, beds str. N-S, dip 45 E.
Sta. 43 - Ku, str. N45W, dip 7 NE.
Sta. 44 - Ku-Kl contact, beds str. N40E, dip 5 NW.
Sta. 45 - Ku-Kl contact, beds str. N45W, dip 60 NE.
Sta. 46 - K-Js contact, beds str. N48W, dip 65 NE.
Sta. 47 - Fault plane, Str. N30W, dip 8 SW, M on Js.
Sta. 48 - M-D contact, beds str. N30W, dip 80 SW, overturned.
Sta. 49 - D-€ contact, beds str. N28W, dip 75 SW, overturned.
Sta. 50 - €-pre€ contact, beds str. N20W, dip 70 SW, overturned.
Sta. 51 - Fault plane, str. N29W, dip 6 SW, M on Tr.
Sta. 52 - Tr-Js contact, beds str. N28W, dip 70 NE.
Sta. 53 - Fault plane, str. N28W, dip 6 SW, M on Tr.
Sta. 54 - €-pre€ contact, beds str. N20W, dip 70 W, overturned.

Draw cross-section of the entire area from NE to SW along a line passing through stations 2 and 13.

GEOLOGIC MAPPING EXERCISE

OIL CREEK, WYOMING


N
Tf
Tf
Ku
Ku
Packer creek
Storm Creek
Canyon Creek
Red creek
Oil creek
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
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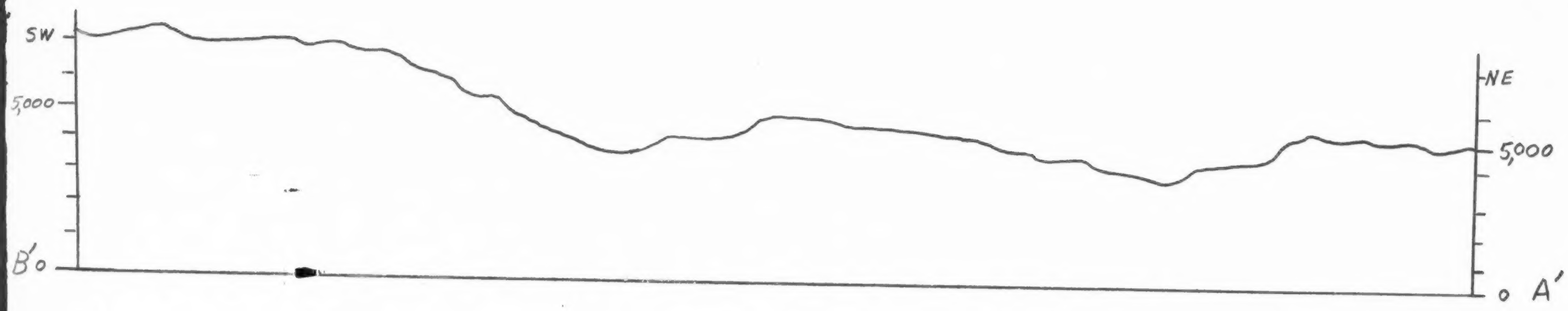
Scale 1" = 1 mile

CROSS-SECTION PASSING THROUGH STATIONS 2 and 13



Tf	Tertiary
Ku	Upper Cretaceous
KL	Lower Cretaceous
Js	Jurassic
R̄	Triassic
P	Permian
M	Mississippian
D	Devonian
Є	Cambrian
PЄ	Precambrian

LESSON 28

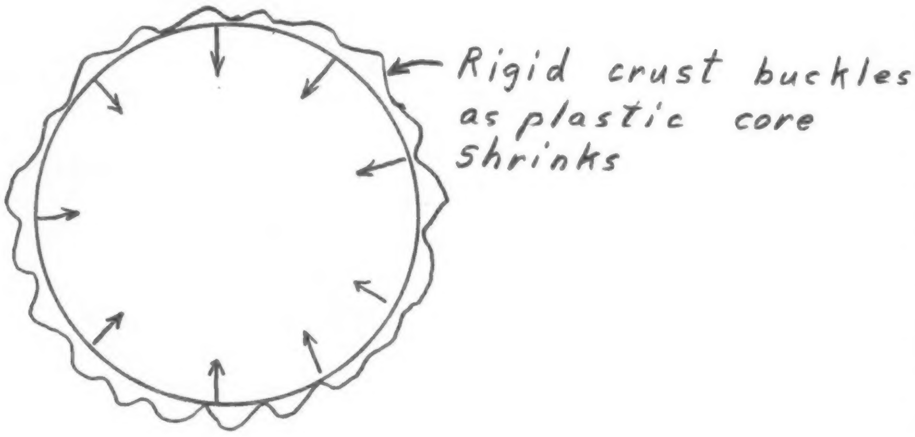
THEORIES OF CRUSTAL MOVEMENT

I. Many theories have been advanced to explain why and how the crust moves.

- A. The theory of isostasy can be applied on a regional basis to explain movements of uplift or subsidence.
- B. However, thrusting and the raising of mountain ranges, particularly those involving folding on a large scale, cannot be explained satisfactorily in this manner.
- C. Therefore, a number of theories have been advanced.

II. Contraction Theory.

- A. The contraction theory proposes that the earth is cooling and shrinking as a result.
- B. Because the crust is rigid, it cannot adjust to the smaller volume and therefore the crust undergoes buckling as heavier strata and lighter strata are lifted and warped upward.



- C. The major shortcoming in this theory lies in the fact that the statement C = 2 r indicates that for every 6.28 miles of crustal shortening the earth must decrease 1 mile in diameter. On this basis the earth would have to shrink about 6,000 miles in diameter to account for all the crustal shortening on the earth or 500 miles for the Alps alone.
- D. Present heat flow evidence indicates that the earth is not losing heat to space as rapidly as it is produced by radioactive decay. Thus, the earth is not cooling off but in fact, may be heating up slightly.

III. Expansion Theory.

- A. The expansion theory accounts for the paleomagnetic drift evidence, the rift valleys, etc.

B. The theory also accounts for the apparent formation of new crustal material in the oceanic rift valleys.

C. The theory does not account for the overthrusts as evidence of contraction.

D. The heating is not sufficient to explain the existing crustal changes.

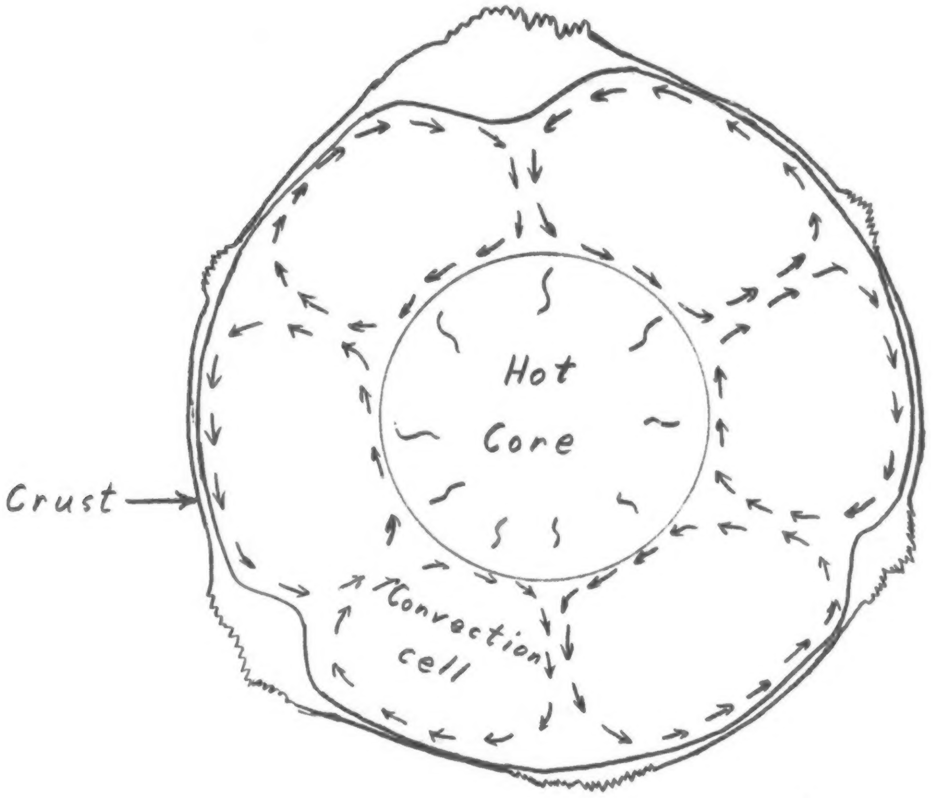
IV. Convection Theory.

A. The convection theory states that the material in the mantle rises and sinks according to its density forming convection currents similar to those in a container of heated water.

B. Heat from the core causes expansion and decreasing density resulting in a plastic upward flow of rocks into the mantle.

C. Cooling near the crust causes an increase in density due to contraction and a plastic flow downward results.

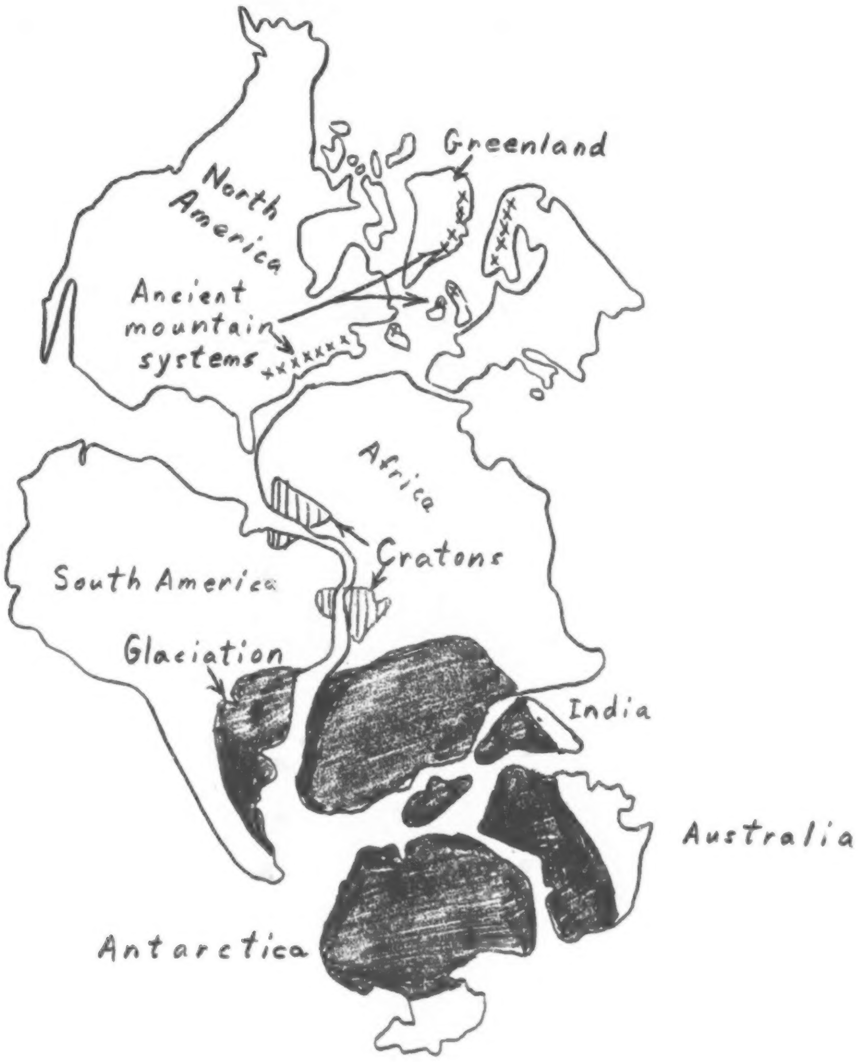
D. Evidence: rift valley systems throughout the world.



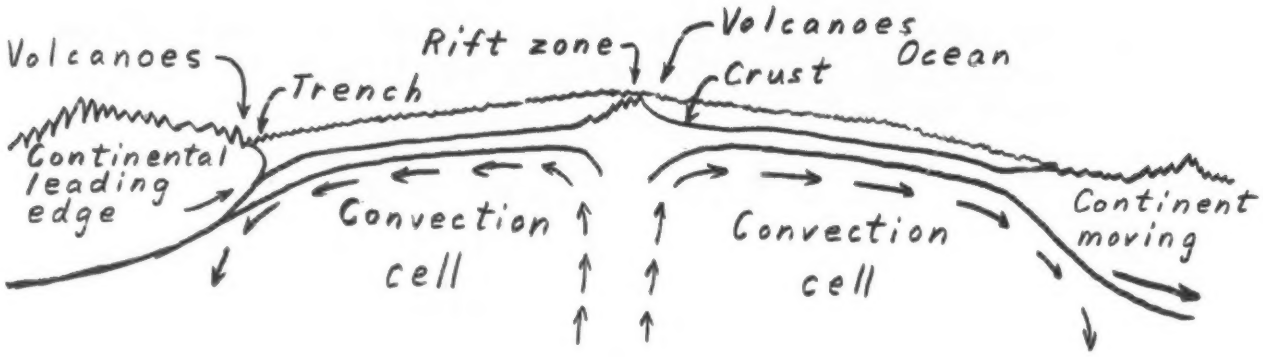
V. In 1912 Alfred Wagner proposed that the continents were drifting.

A. This theory has been proposed to account for diastrophic movements and faulting and folding along the edges of the continents.

B. The theory proposes one large original continent called Gowandaland composed of granite floating on the basaltic ocean basin.


Greenland
North America
Ancient mountain systems
Africa
Cratons
South America
Glaciation
India
Australia
Antarctica

C. The theory proposes that convection currents pushed the continents around (drift) causing the formation of mountain ranges on their leading edges.


Volcanoes
Trench
Rift zone
Volcanoes
Crust
Ocean
Continental leading edge
Convection cell
Convection cell
Continent moving

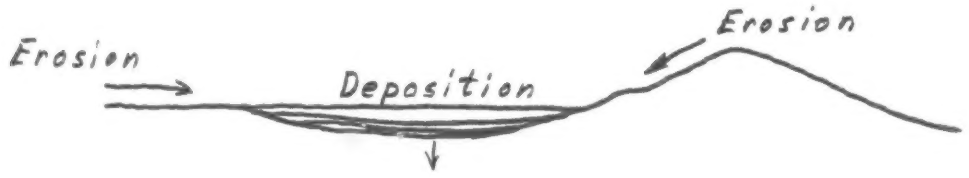
D. Recent drilling has confirmed the lack of granite or ancient sediments on the ocean floor which should be missing if the continents are drifting.

E. Other studies of rock magnetism, rock type, rock structure, and fossil correlation support the theory.

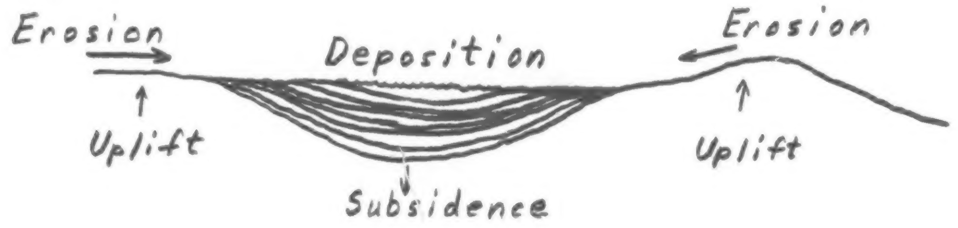
VI. While continent drift can account for the mountain ranges along the leading edges of crustal blocks, trenches and rift zones; it cannot explain the mountain ranges along the trailing edges of blocks such as the Appalachians. These can be explained by the so-called geosynclinal theory.

A. The geosynclinal theory functions as follows:

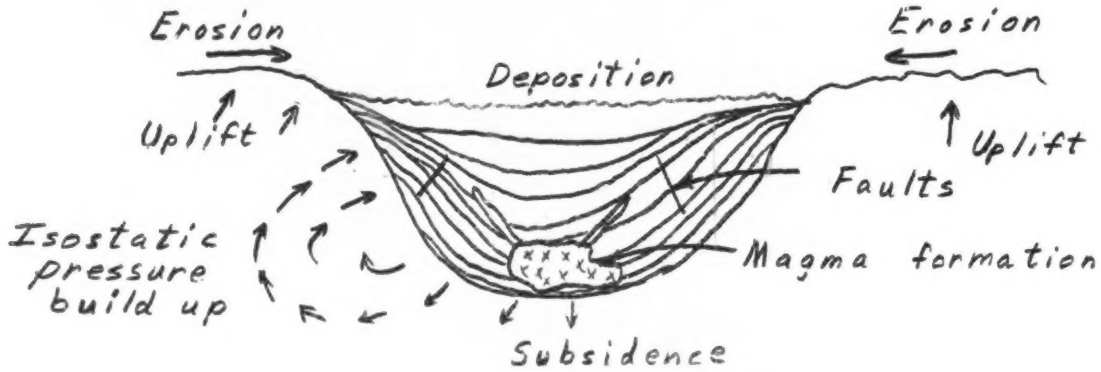
1. Deposition of sediments in an area causes isostatic subsidence.


Erosion
Erosion
Deposition

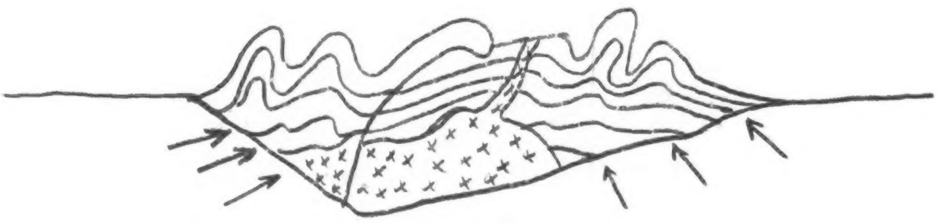
2. As time progresses the deposits become thicker and the resulting displacement increases.


Erosion
Deposition
Erosion
Uplift
Uplift
Subsidence

3. Eventually the pressure of the displaced mantle material and the pressure of overlying sediments cause structural displacement which allows the material to melt or become plastic.



4. As pressure builds up on the plastic mass, folding and faulting occur on a massive scale usually accompanied by volcanism as the entire mass is uplifted.



Isostatic pressure causes uplift and builds mountain range

5. Subsequent erosion and the removal of material result in isostatic readjustment eventually eroding the entire range to base level and exposing the old roots of the mountain range.

VII. Summary.

While there is evidence for and against each of the above theories, it is generally conceded that Isostasy, Convection, and the Continental Drift theories act in some combination to produce diastrophic movements. Present evidence tends to favor some form of the Continental Drift theory. The geosynclinal theory is generally accepted as being a reasonable explanation for the formation of mountains similar to the Appalachians.

LESSON 29, Introduction

GEOLOGIC TIME

Objectives:

1. To develop a concept of the history and problems involved in establishing a geologic time scale.
2. To develop an understanding of the techniques employed in establishing a series of past events and the time required for their occurrence.
3. To introduce the Geologic Timetable.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 19.
2. FOCUS ON EARTH SCIENCE, Chapters 19 and 20.
3. INVESTIGATING THE EARTH, Chapters 17 and 18.

Special References:

Wolfe, et al. EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapter 40.

Gilluly, et al. PRINCIPLES OF GEOLOGY (W. H. Freeman & Company, San Francisco), Chapter 7.

Holmes. PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 13.

Dunbar, Carl O. and Waage, Karl M. HISTORICAL GEOLOGY (John Wiley & Sons, Inc., New York), Chapters 1, 2, and 3.

Activities:

1. What is time?
   ESCP 17-1 — Text 374
   Teacher's Manual 467

2. Creating a model of radioactive decay.
   ESCP 17-4 — Text 378-379
   Teacher's Manual 471-472

3. Investigating the geologic time scale
   ESCP 17-7 — Text 384-385
   Teacher's Manual 475-478

4. Putting the pieces together.
   ESCP 18-6 — Text 399
   Teacher's Manual 495-497

5. Interpreting the history of a model.
   ESCP 18-8 — Text 402
   Teacher's Manual 498-501

6. Rocks reveal ancient climates.
   ESCP 18-10 — Text 403-406
   Teacher's Manual 503-504

6. EXERCISE I

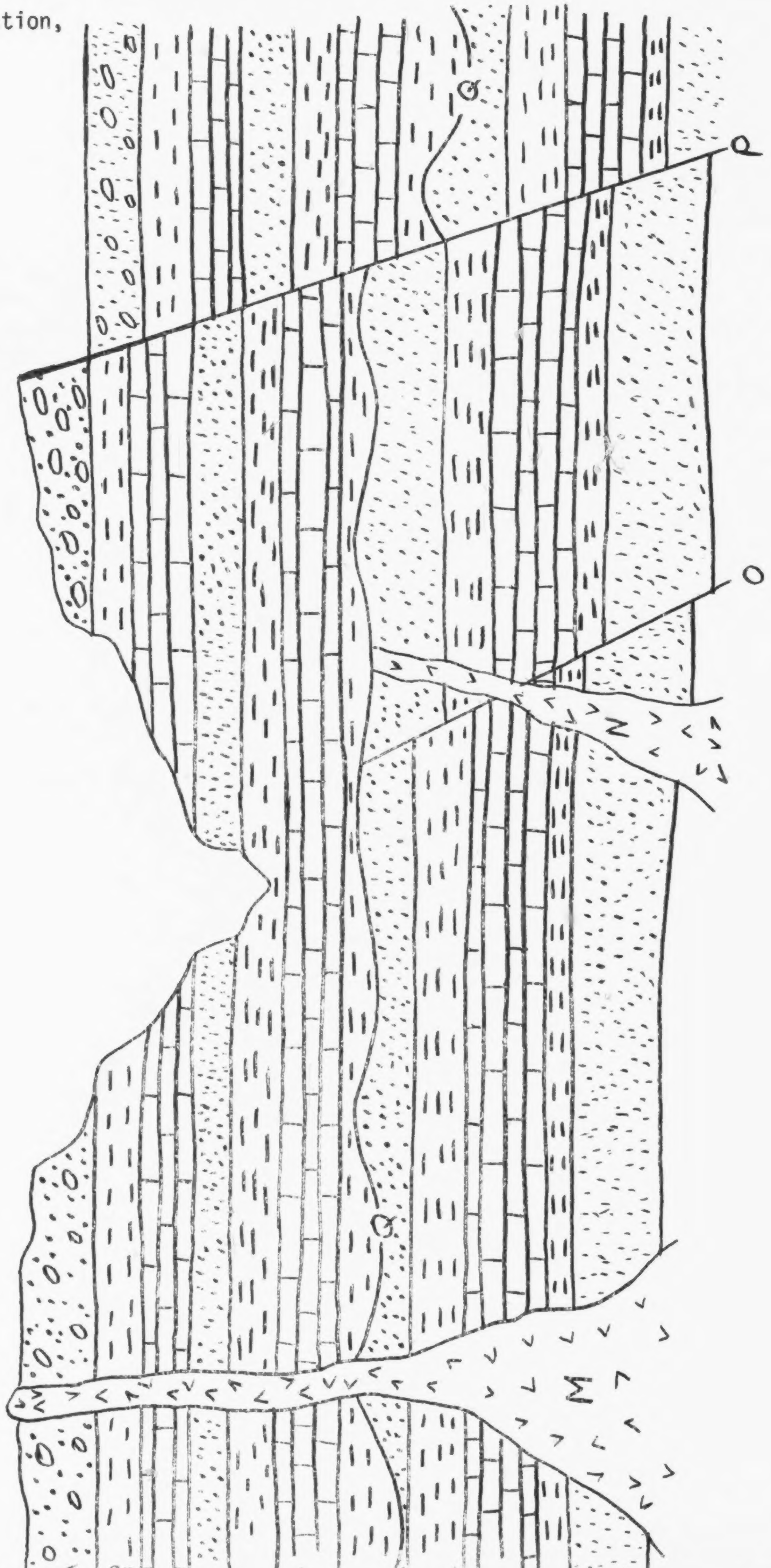
STRATIGRAPHY

Part I.
For each of the following questions, refer to the accompanying stratigraphic section. Blacken completely the letter of the correct answer to the question.

1. The oldest rock in the section is labeled (a) A, (b) M, (c) N, (d) L, (e) Q.
2. The youngest rock in the section is labeled (a) A, (b) M, (c) N, (d) L, (e) Q.
3. Which is older? (a) Igneous intrusion M, (b) Igneous intrusion N.
4. Which is older? (a) Fault O, (b) Fault P.
5. The surface at Q would be called a (a) Fault, (b) Disaster, (c) Unconformity, (d) Intrusion.
6. Which is older? (a) Fault O, (b) Intrusion N.
7. Which is older? (a) Unconformity Q, (b) Fault P.
8. Which is older? (a) Unconformity Q, (b) Fault O.
9. Which is younger? (a) Unconformity Q, (b) Intrusion M.
10. Which is older? (a) Unconformity Q, (b) Intrusion N.

Part II.

List in correct chronological order the proper sequence of events according to relative age. Include sedimentary rock layers, igneous intrusions, faulting, and unconformities. Use letters to indicate events beginning with oldest and working to the youngest.


Q
P
O
N
Q
M

7. EXERCISE II

STRATIGRAPHY

Part I.
Blacken the letter of the word or statement that best answers the question. Refer to the diagram to answer the questions.

1. The structure found in layers G - T is (a) a graben, (b) an anticline, (c) a syncline, (d) a thrust fault.

2. Which igneous intrusion is oldest? (a) X, (b) Y, (c) Z.

3. Which igneous intrusion is youngest? (a) X, (b) Y, (c) Z.

4. Which fault is older? (a) Fault V, (b) Fault W, (c) Cannot tell from available data.

5. The line labeled U is (a) a fault, (b) a dike, (c) an angular unconformity, (d) a disconformity.

6. The oldest rock in the structure is (a) F, (b) T_1, (c) Y, (d) A, (e) P.

7. Between strata E and strata F, intrusion Z would be considered a (a) dike, (b) sill, (c) laccolith, (d) stock, (e) batholith.

8. Fault V is a (a) normal fault, (b) reverse fault.

9. Fault W is a (a) normal fault, (b) reverse fault.

For questions 10 - 15, blacken the letter of the structure that is the oldest of the two structures listed.

10. (a) Intrusion X, (b) Fault V.

11. (a) Intrusion X, (b) Unconformity U.

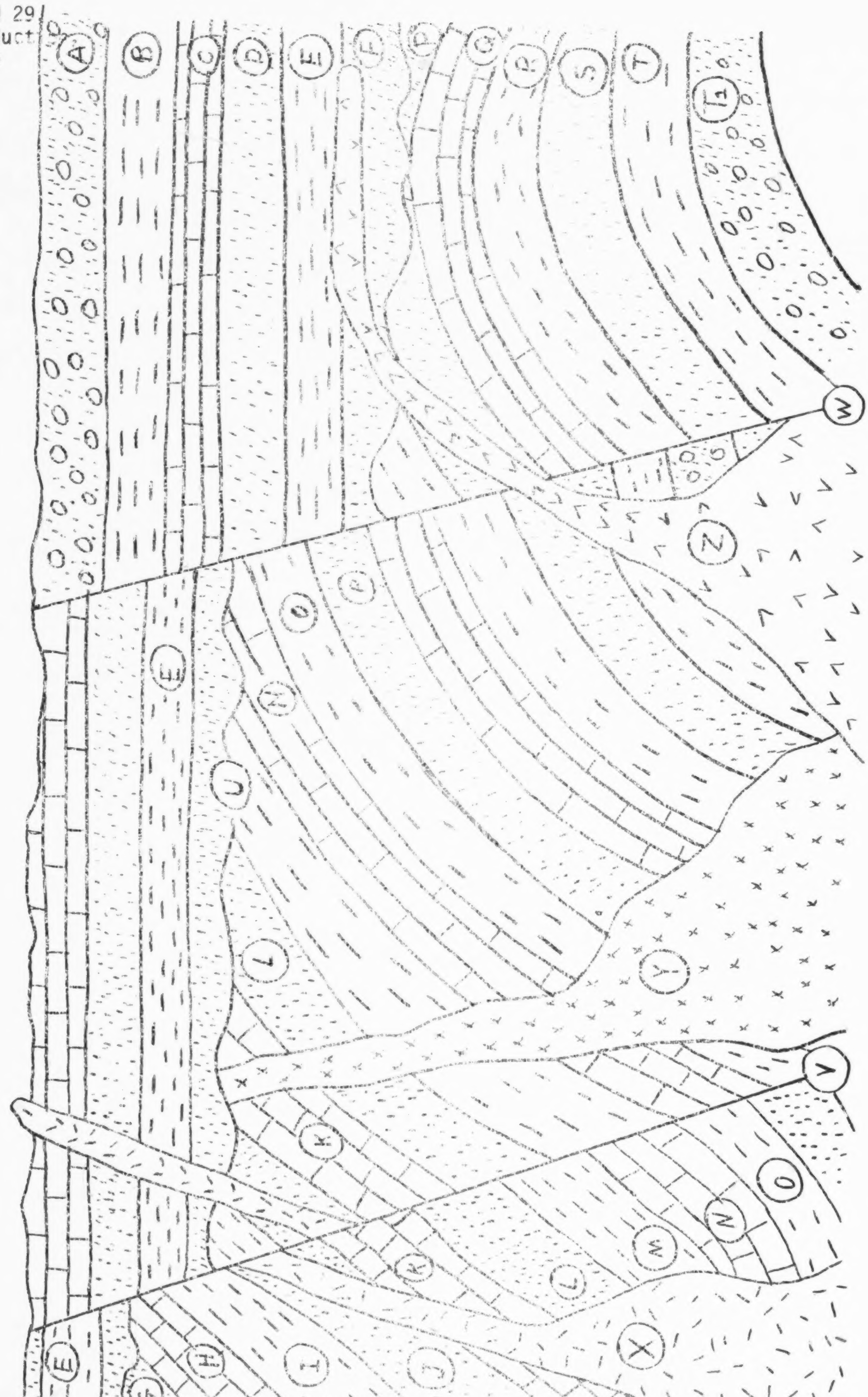
12. (a) Intrusion Y, (b) Fault V.

13. (a) Intrusion Y, (b) Unconformity U.

14. (a) Intrusion Z, (b) Fault W.

15. (a) Intrusion Z, (b) Unconformity U.

Part II.
Write a complete geological sequence of events. Include each sedimentary layer, fault, unconformity, and intrusion in the order of their occurrence. (Put the oldest on the bottom.)


A
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F
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Q
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S
T
T1
W
Z
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Y
V
O
N
M
L
K
X
J
I
H
G
E

8. STRATIGRAPHY EXERCISE

Part I.

INSTRUCTIONS: The following questions refer to the cross section. For the cross section assume that no beds are overturned.

_____ 1. The oldest rock in the section is labeled (1) A, (2) J, (3) F, (4) L.

_____ 2. The oldest rock was deposited in (1) a molten state, (2) a desert area, (3) a beach, (4) clear, warm sea water.

_____ 3. Where is the best place to fish (1) R, (2) S, (3) W, (4) P.

_____ 4. What are the relative ages of the igneous rocks? (1) D older than A, (2) A older than D.

_____ 5. In what sedimentary rock would you expect to find eroded fragments of igneous rock D? (1) N, (2) G, (3) A, (4) P.

_____ 6. In what sedimentary rock would you expect to find eroded fragments of igneous rock A? (1) Y, (2) N, (3) D, (4) P.

_____ 7. What are the relative ages of igneous intrusive D and fault K? (1) D is older than K, (2) K is older than D.

_____ 8. What is the absolute age of igneous rock D? (1) 200 m.y., (2) greater than 200 m.y., (3) less than 200 m.y., (4) unknown.

_____ 9. What are the relative ages of sedimentary rock P and sedimentary rock V? (1) P is older than V, (2) V is older than P.

_____ 10. What seems to be the cause for the ridge at R? (1) location of stream, (2) igneous dike, (3) faulting.

_____ 11. The stream W is flowing south toward the observer. What rock forms most of the valley wall (under the alluvium)? (1) sandstone, (2) igneous rock, (3) limey shale.

_____ 12. What rock type underlies most of the alluvia along the present valley floor? (1) sandstone, (2) igneous rock, (3) limey shale.

_____ 13. Features at P are (1) eroded remnants of an ancient valley floor, (2) eroded remnants of an ancient roadbed, (3) remnant roadbeds of eroded ancients.

_____ 14. Has the valley been deepened by stream erosion? (1) Yes, (2) No.

_____ 15. Of the following types of bedrock in the valley, which would usually be most easily eroded? (1) sandstone, (2) igneous rock, (3) limey shale.

_____ 16. With the further passage of time and assuming the stream is competent to erode the bedrock, what prediction would you make as to the future location of the stream? (1) shift to the east, (2) shift to the west, (3) give up and go home.

_____ 17. This area is at present dry land. It was also dry land in the past; once during the interval (1) 20 m.y. to 185 m.y. ago, (2) 185 to 200 m.y. ago, (3) 200 to 265 m.y. ago, (4) 265 to 320 million years ago.

_____ 18. And earlier during the interval (1) 20 to 185 m.y. ago, (2) 185 to 200 m.y. ago, (3) 200 to 265 m.y. ago, (4) 265 to 320 million years ago.

_____ 19. Of these two times during which the area was dry land, the land probably stood higher above sea level during the (1) earlier time, (2) later time.

_____ 20. The facies change in rock unit N tells us that the sediment source area lay to the (1) east, (2) west of the area shown on the cross section.

_____ 21. The youngest formation in the section is (1) R, (2) L, (3) O, (4) V.

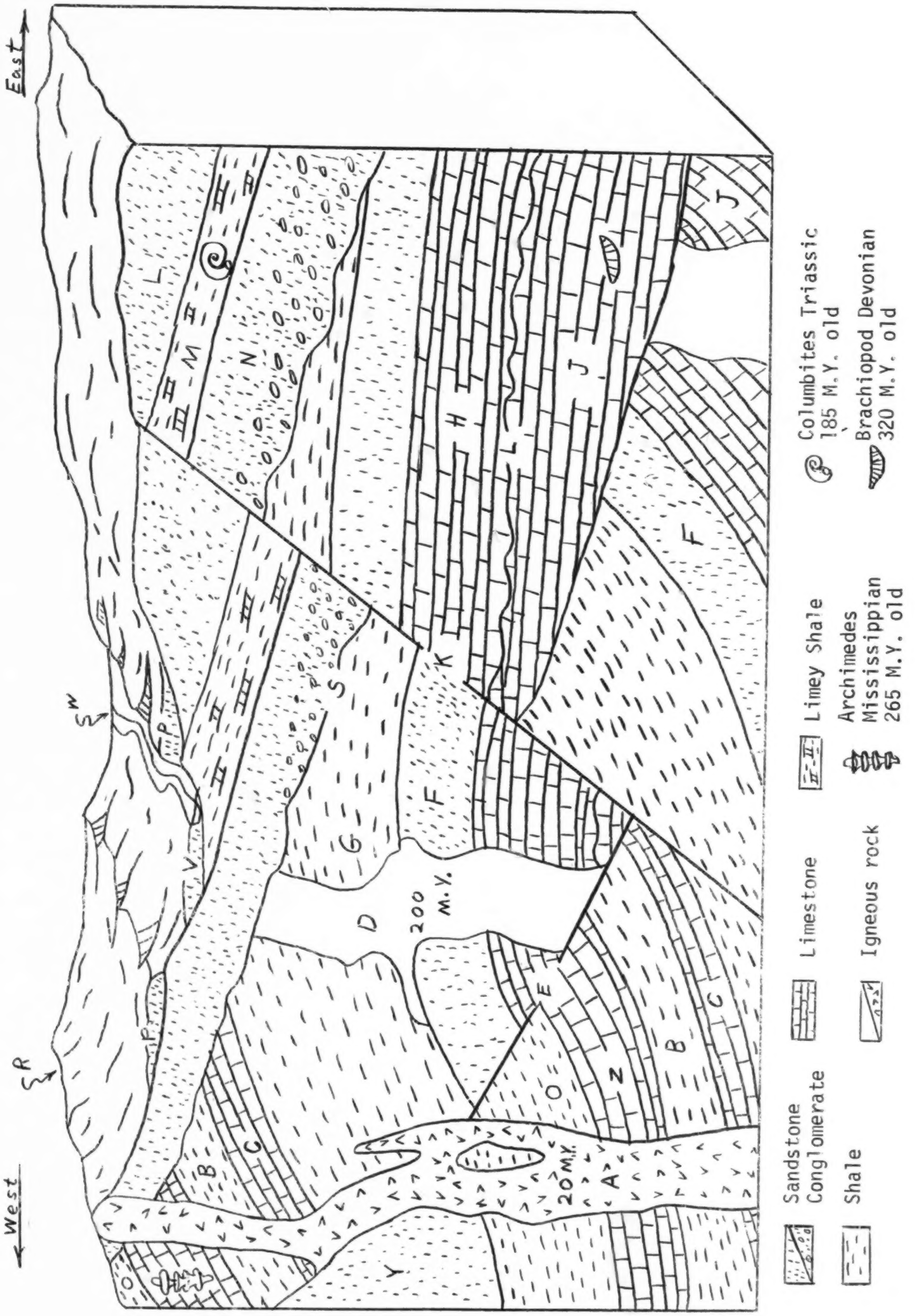
_____ 22. The origin of the youngest formation is (1) igneous activity, (2) sand deposited near shore, (3) hardened layers of mud, (4) flood plain deposition.

_____ 23. The anticline in the section was formed between (1) 20 and 185 m.y. ago, (2) 185 to 200 m.y. ago, (3) 200 and 265 m.y. ago, (4) 265 and 320 million years ago.

_____ 24. Which feature is older? (1) igneous dike A, (2) fault K, (3) both same age, (4) cannot tell from evidence.

_____ 25. The feature labeled E is (1) an unconformity, (2) a normal fault, (3) a thrust fault.

Part II.
Write a complete geological sequence of events. Include each sedimentary layer, fault, unconformity, and intrusion in order of their occurrence. (Put the oldest on the bottom.)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20 M.Y.
Z
O
E
B
C
D
200 M.Y.
G
F
V
P
P
S
K
F
H
J
J
L
M
N
L
F
Sandstone
Conglomerate
Shale
Limestone
Limey Shale
Igneous rock
Archimedes
Mississippian
265 M.Y. old
Columbites Triassic
185 M.Y. old
Brachiopod Devonian
320 M.Y. old

STRATIGRAPHIC DIAGRAM

LESSON 29

GEOLOGIC TIME

I. Introduction.

The problem of the age of the earth has plagued earth scientists for many years. Scholars in the middle ages generally agreed that the earth could not be less than 5,000 nor more than 6,000 years old. One scholar, James Ussher, set the earth's beginning at 9:00 a.m. on October 26 of the year 4004 B.C. There were other problems in explaining fossils of ancient sea life in rocks or mountain tops and explaining the volume of rock and how it was formed.

A. The first attempt at explanation was made by Abraham Werner (1749-1815).

1. He believed that the rocks were precipitated from sea water during the great flood.

2. He subdivided all the rocks into a sequence.

a. Alluvian (later became Cenozoic-Tertiary).

b. Secondary (later became Mesozoic).

c. Transition (later became Paleozoic).

d. Primary (later became Precambrian).

B. The present geologic timetable was developed by trial and error during the last 200 years. The scale is still being changed today as new evidence is uncovered.

C. It was not until about 1833 that a time scale was developed that could apply with reasonable certainty around the world.

II. The geologic timetable was developed on the theory that the passage of geologic time has been accompanied by certain events that are recorded in the rocks.

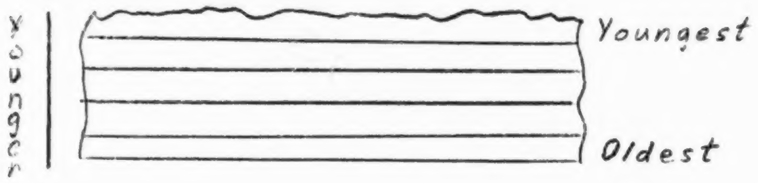
A. Uniformitarianism - the rate of processes and the processes happening today are the same as those that have been acting throughout the ages. The present can be used as a "key" to the past - principle established by Charles Lyell and James Hutton.

B. Proper interpretation of the earth's history is impossible without an understanding of the processes that have been acting throughout time.

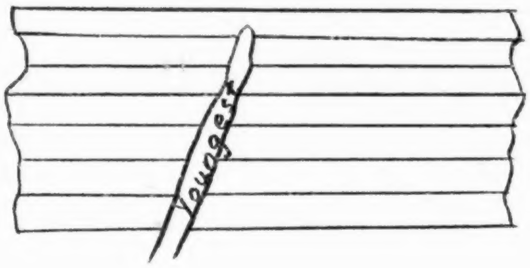
III. Techniques.

A. The principal technique which has been in use in the sub-branch of geology is known as stratigraphy. The principal rule of stratigraphy is that of the "Order of Superposition."

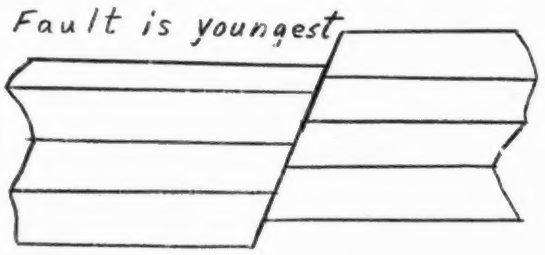
1. Layers at the bottom of a series are older than the rocks at the top. (Exception: Rare cases where sedimentary rocks have been overturned.)



2. Igneous rocks are younger than the rocks into which they intrude.



3. Faults are younger than the youngest bed cut by the fault.



B. Stratigraphic features used as evidence in sedimentary rocks include:

1. Sedimentary rocks are laid down one layer at a time.

2. Certain kinds of rocks are laid down only under certain conditions.

3. The fossils that occur in a rock may indicate time, conditions, and climate.

4. There are places where no deposits occurred or where erosion was the dominant process during a particular period of time.

5. Sediments may be warped, broken, or intruded.

6. Contact metamorphism may be present where rock has been intruded and is often helpful in determining time sequence.

C. Fossils are used in determining the relative age of a rock:

1. By applying what is known about previously studied areas containing fossils to the area being studied.

2. By using established index fossils.

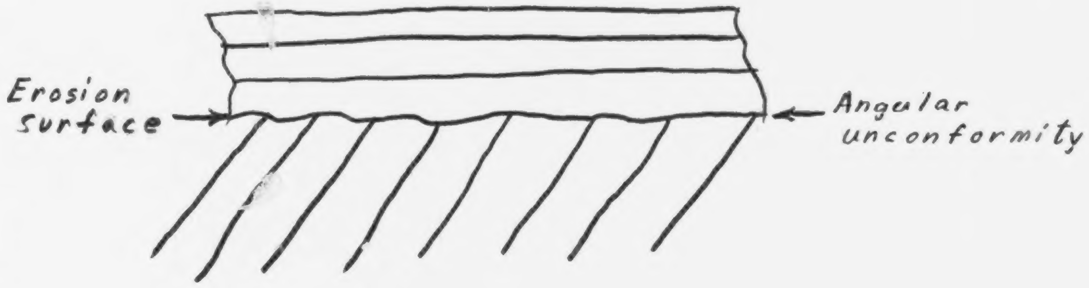
D. Since stratigraphy involves finding clues in the rock structure to determine the relative ages of parts of the structure the time scale developed is relative.

1. Relative Time Scale - A scale based on a sequence of events.

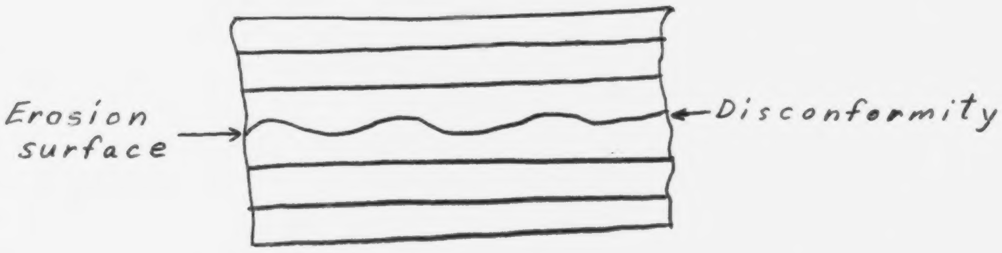
2. Ideally, events in geologic history should be dated in relation to the present in addition to being arranged in a relative sequence.

3. However, parts of the rock record are missing because of erosion. The eroded surfaces in the rock record are called unconformities.

a. Angular Unconformity - If beds above and below the surface are not parallel, the unconformity is said to be angular.



b. Disconformity - If the beds above the unconformity are parallel to those below, the unconformity is said to be a disconformity.



IV. Absolute ages refer to definite figures indicating "how long ago" an event occurred.

- A. Early attempts to establish an absolute time scale included:
    - 1. Salt content of the oceans - How much salt reaches the ocean per year? Relate time to present salt content assuming the oceans were created as fresh water.
    - 2. Rate of erosion - Estimate time for erosional features to reach present stage of development.
    - 3. Both methods are faulty due to wide variations in the amount of erosion and deposition with changes in conditions.
- B. With the discovery of radioactive dating, a tool was developed for arriving at an absolute time scale.
    - 1. Certain elements undergo radioactive decay.
    - 2. The time it takes for half the material to decay is called the half-life. NOTE: The entire sample does not completely deteriorate in twice the half-life, only half of the remainder.
    - 3. Half-life of some materials used in geologic time determination:
        - a. Uranium ⟶ Lead in 4,500,000,000 years.
        - b. Carbon$_{14}$ ⟶ Carbon$_{12}$ in 5,568 years.
        - c. Many other elements also undergo radioactive decay and can be used.
    - 4. If a sample of rock is analyzed and the amounts of uranium and lead or carbon$_{14}$ and carbon$_{12}$ are known, then the absolute age can be calculated.
    - 5. Oldest rocks dated by this method come from Tanganyika, Africa, and are 3.66 billion years old.
    - 6. Other dated rocks of interest:
        - a. Appalachian Mountains - 1.1 billion years old.
        - b. Kings Mountain, N. C. - 250-350 million years old.

V. The Geologic Timetable: Subdivisions.

   A. The passage of geologic time was accompanied by certain events that are recorded in the rocks.

   B. To subdivide geologic time, it is necessary to pick out natural "punctuation marks", events of great geologic importance and/or magnitude.

      1. An orogeny (mountain building) provides a natural break for the study of earth history.

         a. Mountain building represents an event of worldwide importance.

         b. Major intervals were represented by deposition of sediments in geosynclinal basins.

         c. Each episode of deposition was brought to a close by alleged world-wide orogeny, causing retreat of the seas and subsequent erosion of the sediments.

         d. This erosional period caused a "break" in the depositional history called an unconformity.

      2. Orogeny has been almost completely abandoned as the true basis of dividing geologic time on a world-wide basis because it has been found that it may be restricted to a single continent or portion of a continent.

         a. Unconformities occurring in one area may not appear in another.

         b. During an orogeny on one continent, a complete sequence of sedimentary rock may have been put down in other parts of the world.

      3. Fossils from different rock layers (largely those of the European sequence) are employed as the basis for the comparison with fossils in strata from other parts of the world.

VI. Subdivisions of geologic time are based on strata in Europe (especially Britain, France, and Germany).

   A. Names given to the geologic time scale divisions were first applied to sequences of sedimentary rock that could be distinguished by their characteristics or separated from other sequences.

   B. Most of the names have European origins.
   Five geologic eras and the pronunciation and meaning of their names:

(") = Principal accent mark
(') = Secondary accent mark

1. Cenozoic (see' - no - zo" - ik) = recent-life.
2. Mesozoic (mess' - o - zo" - ik) = middle-life.
3. Paleozoic (pay' - lee - o - zo" - ik) = ancient-life.
4. Proterozoic (prot' - er - o - zo" - ik) = fore-life.
5. Archeozoic (ar' - kee - o - zo" - ik) = beginning-life.

(NOTE: If the earth is as old as it is thought to be, Precambrian time may represent as much as 85 percent of all earth history.)

C. Periods in the Paleozoic Era:

1. Permian (pur" - mee - un') = For the province of Perm in the Ural Mountains of Russia.
2. Pennsylvanian (penn' - sil - va" - ni - un) = For the state of Pennsylvania.
3. Mississippian (miss' - i - sip" - i - un) = For the Upper Mississippi Valley (The Mississippian and Pennsylvanian periods are used in the United States in place of the European period known as the Carboniferous).
4. Devonian (dee' - vo" - nee - un) = For Devonshire, England.
5. Silurian (si - lu" - ri - un) = For the Silvres, an ancient Wales tribe.
6. Ordovician (or - doe - vish" - un) = For an ancient Celtic tribe which lived near the Type location in Wales.
7. Cambrian (kam" - bri - un') = From the Latin word Cambria, meaning Wales.

D. Periods in the Mesozoic Era:

1. Cretaceous (kree' - tay" - shus) = From the Latin word creta, meaning "chalk"; refers to chalky limestones such as those exposed in the white cliffs of Dover on the English Channel.
2. Jurassic (ju' - rass" - ik) = For the Jura Mountains between France and Switzerland.

3. Triassic (try' - ass" - ik) = From the Latin word trias, meaning "three"; refers to the natural three-fold division of these rocks in Germany.

E. Periods of the Cenozoic Era:

1. Quaternary (kwah" - tur - nuh - ri) = Implying "fourth generation."

2. Tertiary (tur" - shi - er - i) = Implying "third derivation."

(NOTE: The names of these two periods were derived from a system of classification which divided all of the earth's rocks into four groups. The two divisions in the Cenozoic are the only names from this system still in use.)

F. The standard rock column of today is still based on the strata of Western Europe and is universally used as the basis for the geologic time scale.

G. Most of the names have European origin.

1. Some names are descriptive:

   a. Cretaceous (chalky).

   b. Carboniferous (coal bearing).

2. Some were names of geographical localities:

   a. Devonian (Devonshire, England).

   b. Jurassic (Jura Mountains).

   c. Cambrian (Cambridge, England).

   d. Permian (Perm, Russia).

   e. Mississippian and Pennsylvanian are named for areas within the United States. These divisions of the Carboniferous are not used in Europe.

3. Some were named for ancient tribes that inhabited the area.

   a. Silurian (for the Silures).

   b. Ordovician (for the Ordovician tribe).

GEOLOGIC TIME CHART

AGE DIVISIONS			DOMINANT LIFE		TIME			
ERA	PERIOD	EPOCH	ANIMAL	PLANT	DURATION in millions of years era	period	epoch	BEGINNING millions of years
CENOZOIC	QUATERNARY	Recent	man		65.011	2-3	0.011	
		Pleistocene					1-3	2-3
	TERTIARY	Pliocene	mammals bony fish birds shell fish arthropods	flowering trees and shrubs		62-63	9-10	12
		Miocene					14	26
		Oligocene					11-12	37-38
		Eocene					16	53-53
		Paleocene					11-12	65
MESOZOIC	CRETACEOUS		reptiles	conifers cycads ginkgos ferns	160	71		136
	JURASSIC					54-59		190-195
	TRIASSIC					30-35		225
PALEOZOIC	PERMIAN			scale trees	345	55		280
	PENNSYLVANIAN	Carboniferous	amphibians insects	cordates tree ferns calamites				
	MISSISSIPPIAN					65		345
	DEVONIAN		sharks	primitive scale trees and tree ferns		50		395
	SILURIAN		lungfish	psilophytes		35-45		430-440
	ORDOVICIAN		coral brachiopods			70-80		500
	CAMBRIAN		echinoderms trilobites	fungi algae		70		570
PRE-CAMBRIAN	Grenville Orogeny		beginning of primitive plant and animal life		3600+			1000*
	Oldest Known Rocks in North America							3200*
	Oldest Known Rocks (Murmansk Area)							3400*
	Probable Age of the Earth							4600?*

* Dates adapted from Oregon table. Table adapted from Oregon State Geologic Survey Time Table by F.L. Beyer and R. G. Whisnant. Dates taken from U.S. Geologic Survey - Geologic Names Committee 1968.

LESSON 30, Introduction

HISTORICAL GEOLOGY

Objectives:

1. To develop an overall concept of the events that occurred in the United States prior to the end of the Paleozoic era.
2. To develop a concept of the evidence concerning the development of life up to the beginning of the Mesozoic era.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 21.
2. FOCUS ON EARTH SCIENCE, Chapter 20.
3. INVESTIGATING THE EARTH, Chapters 18, 19, and 20.

Special References:

Wolfe, *et al.* EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 40, 41, and 42.

Dunbar, *et al.* HISTORICAL GEOLOGY (John Wiley & Sons, Inc., New York), Chapters 1-13.

Gilluly, *et al.* PRINCIPLES OF GEOLOGY (W. H. Freeman & Company, San Francisco), Chapter 22.

Holmes, PRINCIPLES OF PHYSICAL GEOLOGY (Ronald Press, New York), Chapter 13.

Activities:

1. Investigating a footprint puzzle.
   ESCP 19-5 — Text 416
   Teacher's Manual 522-523

2. Fossils are clues to earth history
   ESCP 19-8 — Text 419
   Teacher's Manual 527

3. Investigating variation and evolution
   ESCP 19-10 — Text 421
   Teacher's Manual 529-531

4. Investigating Precambrian rocks
   ESCP 20-2 — Text 435
   Teacher's Manual 546-548

LESSON 30

HISTORICAL GEOLOGY

I. The Cosmic Era - Time of formation of the earth.

A. Several hypotheses have been presented as to the formation of the earth.

B. The Nebular or Dust Cloud Hypothesis appears to be the best.

II. The Azoic Era was a period without life; the earth was undergoing many physical and chemical changes.

A. Development of core, mantle, and crust took place.

1. Temperature rose allowing separation according to density.

2. The crust at first was thin and weak, so there probably was great instability in the crust with continuous thrusting up and wearing down of mountain masses and upwellings of lava and volcanic eruptions.

3. The surface may have resembled that of the moon.

B. Development of an atmosphere.

1. Early atmosphere probably CH_4 (methane), water vapor, NH_3 (ammonia). All derived from solids in the dust cloud.

2. Photochemical processes allowed these early gases to change.

a. Primitive plants probably developed early (free-floating microorganisms).

b. Primitive animals could not develop until oxygen was supplied by photochemical dissociation of water vapor.

1) $2H_2O \xrightarrow{\Delta} 2H_2 + O_2$

2) Eventually present atmospheric proportions were reached.

a) $CH_4 + 2O_2 \xrightarrow[\text{light}]{} CO_2 + 2H_2O$

b) $4NH_3 + 3O_2 \xrightarrow[\text{light}]{} 6H_2O + 2N_2$

C. Development of the oceans.

1. Granitic rocks were gathered together to form the continental masses, probably due to convection currents in mantle.

   2. Heavier basaltic rocks formed the ocean basins.
   3. It is generally agreed that water was supplied from freeing of water by volcanic eruptions.

D. There was widespread volcanic activity.

III. Precambrian Era (Outline of geologic time with emphasis on geologic events and evolution of life forms in North America).

A. The Precambrian Era includes the whole of geologic time before the earliest Cambrian sediments were deposited.

   1. 80 - 85% of all the earth's history.
   2. The least is known about this era because of the metamorphosis of the geologic rock record and an absence of fossils.

B. Subdivisions of the Precambrian Eras.

   1. Azoic - "without life".
   2. Archeozoic - "very ancient life".
   3. Proterozoic - "ancient life".

C. Continental Shields.

   1. Every continent contains a Precambrian Shield as a nucleus of the continent.
   2. The shield of North America is found almost exclusively in Canada and is called the Canadian Shield.
   3. Precambrian Rocks are found in other areas, but generally are at the surface only at shield areas.
      a. Found in cores of mountains by drilling.
      b. Erosion has uncovered Precambrian rocks in the bottom of the Grand Canyon.

D. Events of the Precambrian Eras.

   1. Within the shields are found complex relationships of sedimentation, intensive deformation, igneous activity, and widespread metamorphism.
   2. North America is thought to have developed from several nuclei of Precambrian rocks, with geosynclinal activity about the edges.

3. The era closed with great crustal upheavals and volcanism. (Killarney - Grand Canyon Revolution)

4. There is a gap between the Precambrian and the Paleozoic Eras called the Lipalian (lost) interval - evidenced by an unconformity.

E. Plant and animal life of the Precambrian Eras.

1. Very little is known because there are few fossils.

2. Algae, bacteria, and other primitive plants were the first inhabitants of the earth.

3. Invertebrate animals lived in Proterozoic waters.

4. Some fossils have been found.

a. Australia - Soft bodied creatures (like jelly-fish and segmented worms – (700 million years old)

b. Ontario - Fossilized plants. (1.3 billion years old)

c. Africa - Algae concretions. (2.7 billion years old)

d. Some fossils have been found in Precambrian rocks in the Grand Canyon.

e. Graphite has been found interbedded and presents a good case for abundant Precambrian life. (Wake County, North Carolina)

IV. The Paleozoic Era can be divided into periods because of repeated submergence and emergence of the land.

A. At the beginning of the Paleozoic era, the present mountain areas in the United States contained geosynclines where marine sediments were accumulating throughout most of the era.

1. Appalachian Geosyncline.

2. Quachita Geosyncline.

3. Cordilleran Geosyncline.

B. Between the geosynclines there was a large interior region which at times during the era was partially submerged.

C. 30,000 - 40,000 feet of rock accumulated in the Appalachian Geosyncline during the era.

D. A group of volcanic islands lay outside the geosynclines and supplied the bulk of the sediment to the geosynclines.

V. The Cambrian Period is the earliest period for which sediments can be found.

   A. Earliest sediments are sandstones, shales, and limestones, and can be found in about half of the 50 states, indicating that Cambrian seas covered much of North America.

   B. The end of the Cambrian Period was marked by folding and faulting in the Vermont region. (Green Mountain disturbance)

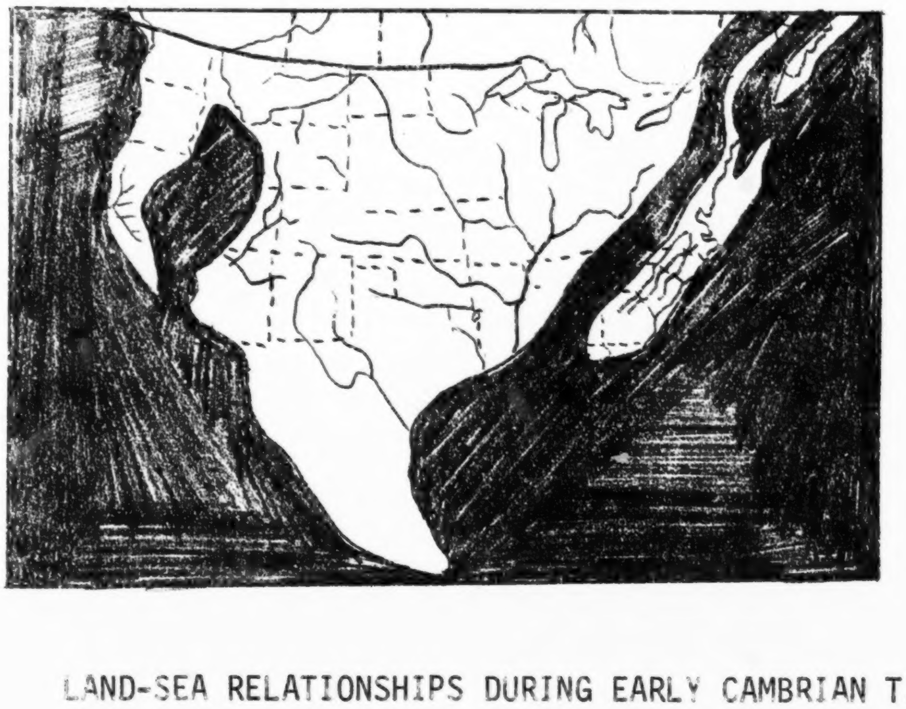
   C. Cambrian sediments contain many fossils indicating marine life.

      1. Plants included seaweed, algae.

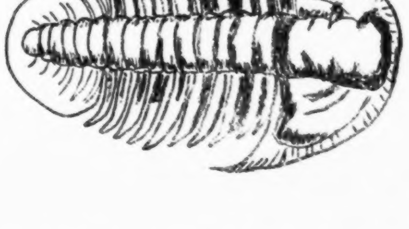
      2. Animal life included Trilobites and Brachiopods.

         a. Trilobites were ancestors of the crab. Size varied from less than one inch long to over 18 inches long.

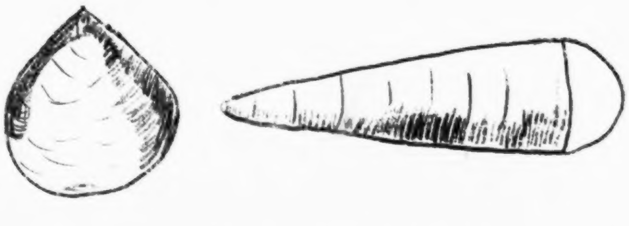
         b. Brachiopods were shell fish resembling a clam.



LAND-SEA RELATIONSHIPS DURING EARLY CAMBRIAN TIME



TYPICAL CAMBRIAN TRILOBITE



TYPICAL CAMBRIAN BRACHIOPOD AND MOLLUSK

VI. The Ordovician Period.

A. There was no widespread land emergence after the Cambrian Period.

1. Sedimentation continued during the period in the continental interior.

2. Greatest invasion of the sea into North America occurred during the Ordovician Period.

3. The bulk of Ordovician sediments are limestones, but some shales were deposited. (Example: The shale underlying Niagara Falls.)

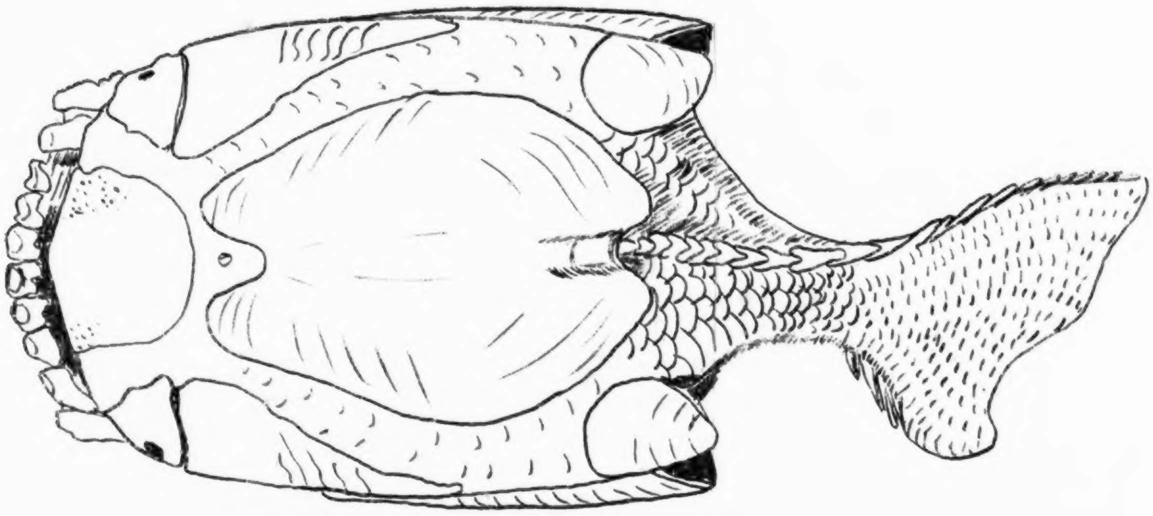
4. The end of the Ordovician Period was marked by the Taconic Disturbance. (Uplift in New York-Massachusetts area)

B. Plant and animal life of the period were marine.

1. The first vertebrate appeared during this period.

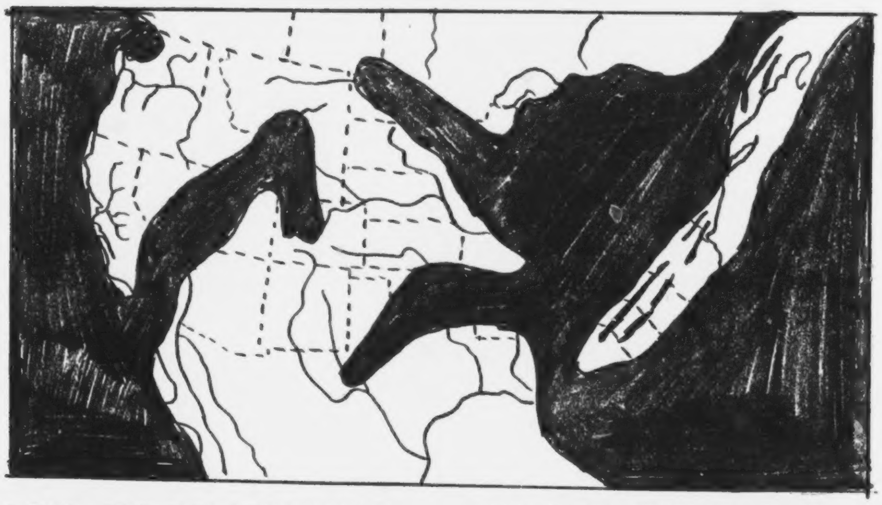
a. vertebrates are animals with backbones.

b. The first vertebrates were a group of fish called ostracoderms.



TYPICAL LOWER DEVONIAN OSTRACODERM (ORDOVICIAN FRAGMENTS ONLY). Ordovician genus is believed to have been similar in appearance.

2. Invertebrates still dominant (nautaloids, trilobites, brachiopods, graptolites, coral, gastropods (snails), cephalopods (nautilus), and pelecypods (clams).



LAND-SEA RELATIONSHIPS - EARLY ORDOVICIAN TIME

VII. The Silurian Period was characterized by renewed invasion of the continental area by shallow seas.

A. Eroded areas of Ordovician and Cambrian rocks show that they did remain above water for a while after uplift.

1. Sediments include sandstone, shale, limestone, and chemical precipitates (salt and gypsum).

2. Silurian rocks are exposed by streams today. (Example: Niagara Falls owes its existence to a hard Silurian dolomite caprock.)

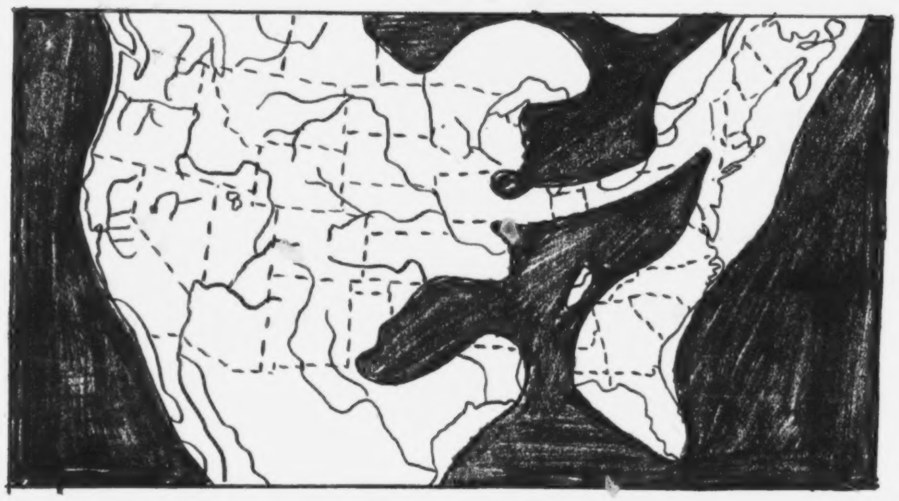
B. Silurian life was predominantly marine, but the first land life emerged.

1. Earliest land animals - scorpions and millipedes.

2. Sea scorpions 8 to 9 feet long.

3. Coral, brachiopods, nautiloids, trilobites.

4. First land plants but fossil evidence is rare.



SEA-LAND RELATIONSHIPS - EARLY SILURIAN TIME

VIII. Devonian Period ("Age of Fishes").

A. No pronounced orogenic movements occurred between Silurian and Devonian.

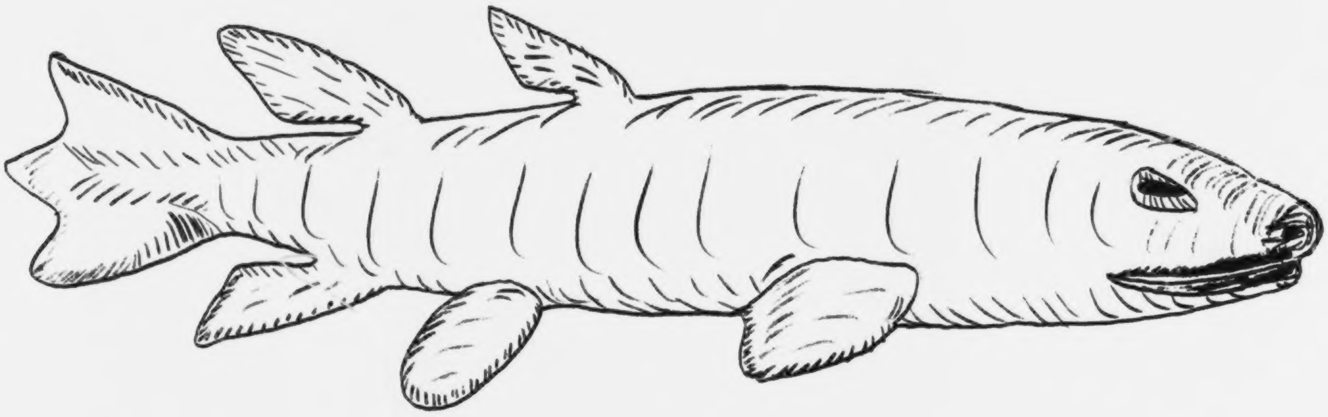
B. The Appalachian geosyncline received sediments during the entire period.

C. Cordilleran geosyncline was above water the first half of the period, but in the latter half, submerged.

D. The Acadian Disturbance marked the end of the period. (The New England area was strongly affected.)

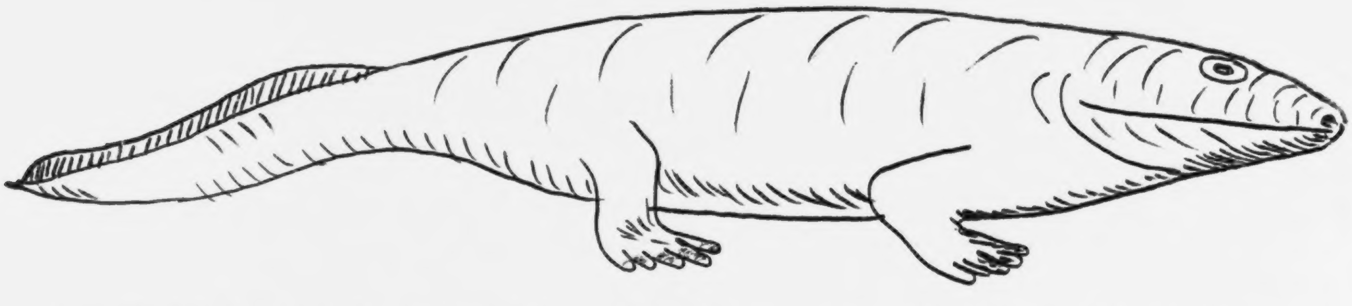
E. The Devonian Period is referred to as the "Age of Fishes."

1. Fish occupied a prominent part of the organic world.
2. Lungfish - could live when lakes or rivers in which they lived dried up part of the year. (Not to be considered a direct evolutionary link from water to land.)
3. More direct link was the lobe-finned fishes.



4. First simple amphibians were found during this period so we might consider that the transition from water to land was beginning.

F. Other life included: invertebrates,(brachiopods, sponges, and corals, etc.) wingless insects.



ICHTHYOSTEGA (First Amphibian - Late Devonian. Closely related to Crossopterygians)

IX. The Carboniferous Period was characterized by coal deposits and is divided in the United States into two distinct periods.

A. The Mississippian Period was marked by another widespread encroachment of marine waters on the continental land mass.

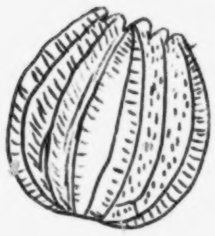
1. Much of the land was covered with swamps.

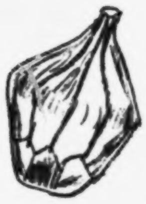
2. Limestone was deposited in the western part of the continent.

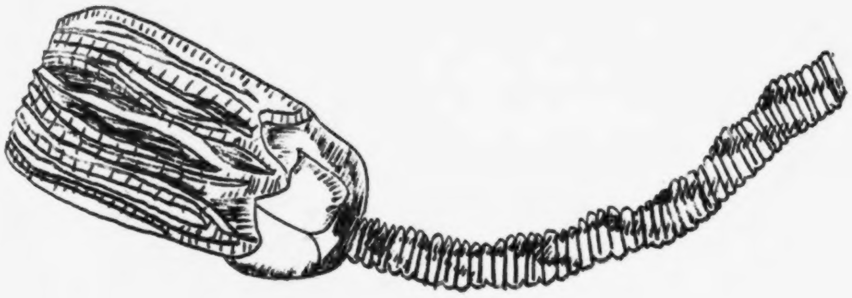
3. Sandstone was predominant in the eastern part of the continent.

B. War seas provided a variety of plant and animal life.

1. Many fossils are found in the limestone of this period.
2. Crinoids and blastoids were common forms of animal life.

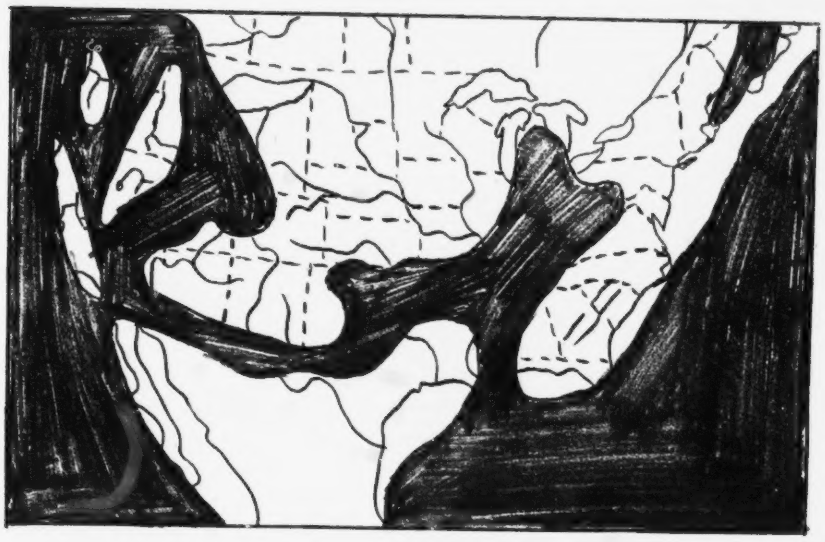




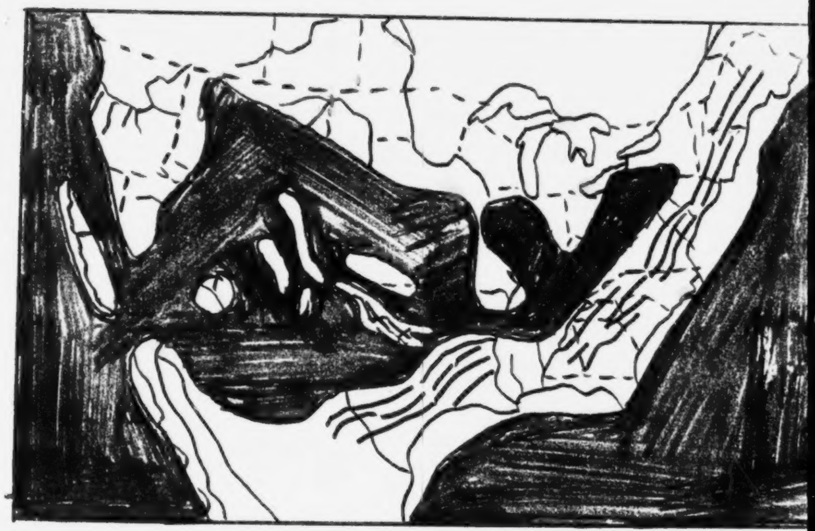


C. The Pennsylvanian Period and the Mississippian Period produced all the major coal fields of the earth.

1. Thick vegetation in swampy regions led to the formation of the thick coal beds.
2. The swamp environment was ideal for plant life. Large ferns, scale trees, seed ferns, and horsetails thrived.
3. Fossils of the periods are abundant.
    a. Over 800 different types of insect fossils have been found.
    b. Included in the insect fossils are cockroaches 4 inches long and dragonflies with 2 foot wingspreads.
    c. Land snail fossils have also been found.
    d. Amphibians had become more abundant.
    e. The first simple reptiles are found in this period.
4. Marine sediments accumulated in the geosynclines.
5. The first signs of orogeny began to develop during the Pennsylvanian Period.



LATE MISSISSIPPIAN TIME



LATE PENNSYLVANIAN TIME

X. The Permian Period marked the beginning of the Appalachian Orogeny which was to end the Paleozoic Era.

A. By the middle of the period, the Appalachian geosyncline was almost entirely above sea level and had ceased to exist by the end of the period.

1. Low swampy lands of the Carboniferous had risen.

2. In place of the geosyncline was a belt of lofty mountains.

3. Few sediments from the Permian Period have been found.

B. The pronounced change in environment brought extinction to many species of life.

1. Evidence of aridity in the form of evaporites.

2. Evidence of glaciation in the form of tillites. (Thought not to have occurred in North America)

3. Seed plants replaced the swamp vegetation. (Vegetation suited to a cooler, drier climate)

4. Reptiles divided into two groups.

a. Root reptiles.

b. Mammal-like reptiles.

5. Trilobites became extinct during the Permian Period.

6. Insects developed.

7. Reptiles made the greatest advances during the Permian Period.

XI. The Appalachian Orogeny.

A. The Appalachian Orogeny reached its climax during late Permian time and marked the end of the Paleozoic Era.

B. The Appalachian "Revolution" consumed about 2/3 of the 50 million years of the Permian Period and lasted into the Mesozoic Era. (Triassic Period)

C. During the Appalachian Orogeny, the crustal portions involved were shortened some 500 miles.

1. In the central and southern Appalachian Mountains we find extensive folds, faults, thrusts, and plutonic dikes formed during the orogeny.

a. The chief effects of the orogeny were folding and thrust faulting.

b. The forces responsible for folding were directed toward the northwest as indicated by the folds and thrust faults.

2. In New England the revolution started earlier and was accompanied by igneous intrusive activity.

3. The present day Appalachians were formed by a number of forces: (Several periods of uplift and several periods of erosion)

a. Original uplifted mountains were eroded to a peneplain.

b. Uplift produced a series of fault basins. (Triassic)

c. Surface again peneplained. (Schooley Peneplain)

d. Peneplain uplifted, tilted seaward, and erosion again is reducing the present Appalachians to a peneplain.

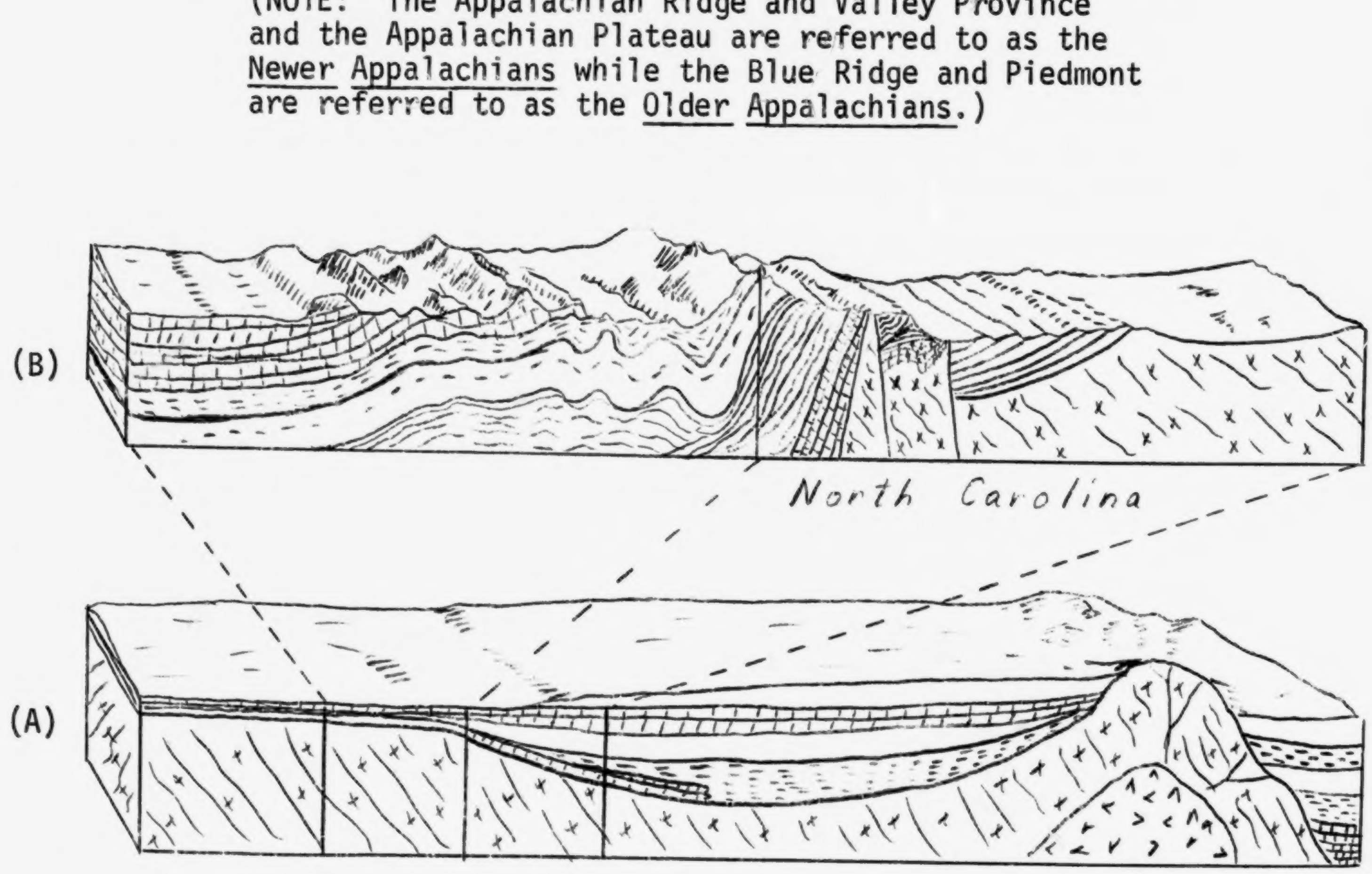
4. The Appalachians consist of several provinces, all geomorphologically different.

a. The Appalachian Mountains consist of numerous parallel and sub-parallel ridges and valleys produced by erosion of anticlines, synclines, and thrust faults.

b. Appalachian Plateau (Cumberland and Allegheny Plateaus) consists of flat or gently folded upper Paleozoic sediments.

c. Blue Ridge Province consists of highly folded Cambrian formations and Precambrian igneous and metamorphic rocks that have been thrust faulted toward the adjacent folded province.

d. Piedmont Province is similar in structure to the Blue Ridge but has been reduced to a lower level by erosion. (NOTE: The Appalachian Ridge and Valley Province and the Appalachian Plateau are referred to as the Newer Appalachians while the Blue Ridge and Piedmont are referred to as the Older Appalachians.)



Evolution of a mountain range: (A) The Appalachian geosyncline at the end of the Paleozoic before mountain building started. (B) The original Appalachian Mountains at the end of the Paleozoic.

LESSON 31, Introduction

HISTORICAL GEOLOGY: THE MESOZOIC AND CENOZOIC

Objectives:

1. To develop an overall concept of the events that occurred in the United States from the beginning of the Mesozoic Era up to the present.
2. To develop a concept of the evidence concerning the development of life from the end of the Paleozoic Era until the present.

References:

1. THE EARTH-SPACE SCIENCES, Chapter 21.
2. FOCUS ON EARTH SCIENCE, Chapter 20.
3. INVESTIGATING THE EARTH, Chapters 18, 19, and 20.

Special References:
Wolfe, *et al.* EARTH AND SPACE SCIENCE (D. C. Heath & Company, Atlanta), Chapters 40, 41, and 42.
Dunbar, *et al.* HISTORICAL GEOLOGY (John Wiley & Sons, Inc., New York), Chapters 14 - 20.

Activities:

1. Investigating Paleozoic rocks in Michigan
   ESCP 20-5 — Text 439
   Teacher's Manual 550-552

2. Investigating the Ice Age puzzle
   ESCP 20-10 — Text 448
   Teacher's Manual 559-560

LESSON 31

HISTORICAL GEOLOGY: THE MESOZOIC AND CENOZOIC

I. The term "Mesozoic" refers to an era of "middle life" during which great reptiles flourished, tapered off, and many became extinct. The era is divided into three periods: Triassic, Jurassic, and Cretaceous.

II. The Triassic Period saw the completion of the Appalachian Orogeny on the Eastern North American continent.

  A. Stream erosion became the dominant geologic process.

  B. Sediments were deposited east of the present Atlantic coast where they are now buried under younger sediments.

  C. In late Triassic, a series of linear faults occurred. Within these fault basins the only record of Triassic sedimentation on the eastern part of North America is found.

    1. These areas formed when block faulting occurred as the now-peneplain surface of the Appalachian Mountains was uplifted.

    2. These fault basins were local in extent and apparently not interconnected.

    3. Included within the sediments there are coal beds, lava flows, and igneous intrusions.

    4. Fossils are not too common, but fresh water fish and some dinosaur fossils are found in places.

    5. The Triassic Basins in North Carolina.

      a. There are two Triassic Fault Basins of note in North Carolina.

        1) The Dan River Basin.
        2) The Deep River Basin.

      b. These troughs formed by the development of faults on the east of the Deep River Basin and the west side of the Dan River Basin.

      c. Sedimentation in these basins gives a record of some of the geologic events.

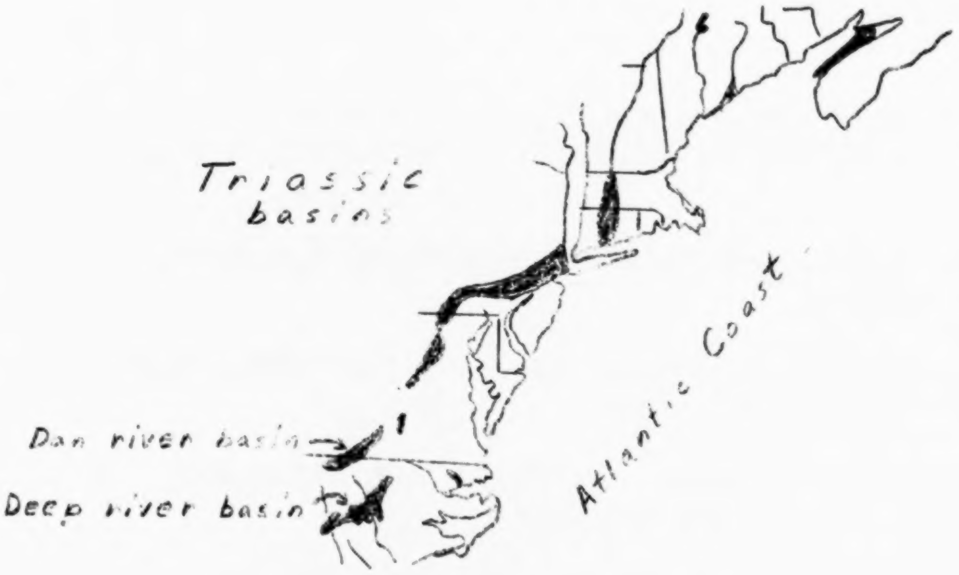
        1) Conglomerates, sandstones, shales, and siltstones were deposited in these basins, along with some coal beds, basaltic flows, sills, and dikes.

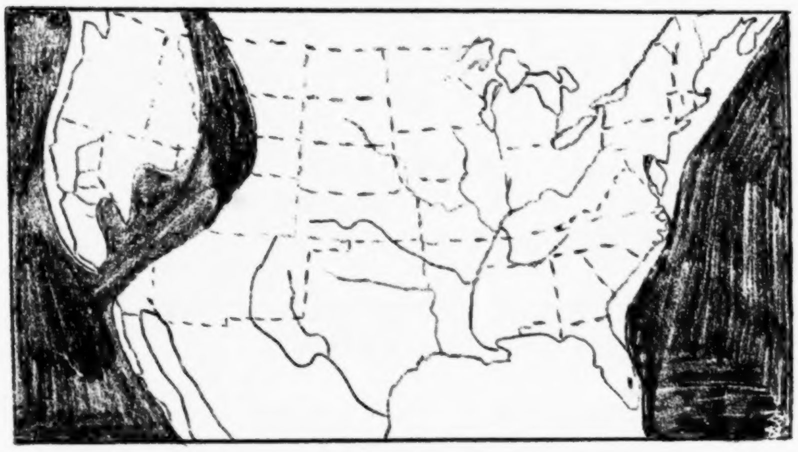
2) Fossils were also formed.

   a) Petrified wood is common.
   b) Recent finds include dinosaur fragments from the Deep River Basin.

D. The western geosyncline was still an active depositional site.

E. Period ended with further uplift in the eastern United States.


Triassic basins
Dan river basin
Deep river basin
Atlantic Coast



LAND-SEA RELATIONSHIP - EARLY TRIASSIC

F. Triassic plant and animal life offers a direct contrast to present life.

1. Fossil plant life of note includes petrified wood found in the Triassic Fault Basins and the Petrified Forest of Arizona.

2. New plants not found previously include large conifers, ginkgo trees (still found today), and cycad palms.

3. Triassic animal life was carried over somewhat from the Paleozoic. (Notable exception: No trilobites)

a. The ancestors of the first birds made progress.

b. The first mammal appeared.

c. Reptiles were the prominent life of the period.

1) Ichthyosaurs.
2) Early dinosaurs.

III. The Jurassic Period is called the "Age of Dinosaurs".

A. The uplifted Appalachians were reduced to a peneplain surface called the Schooley Peneplain.

B. West of the Great Plains in the western geosyncline, deposition was taking place.

C. Some volcanic activity also occurred in the western part of the continent indicating beginning of orogenic activity.

D. Marine life of the period included many invertebrates, fishes, and "sea monster"-type dinosaurs (Ichthyosaurs and Plesiosaurs).

E. The dominant type of land life was the dinosaur.

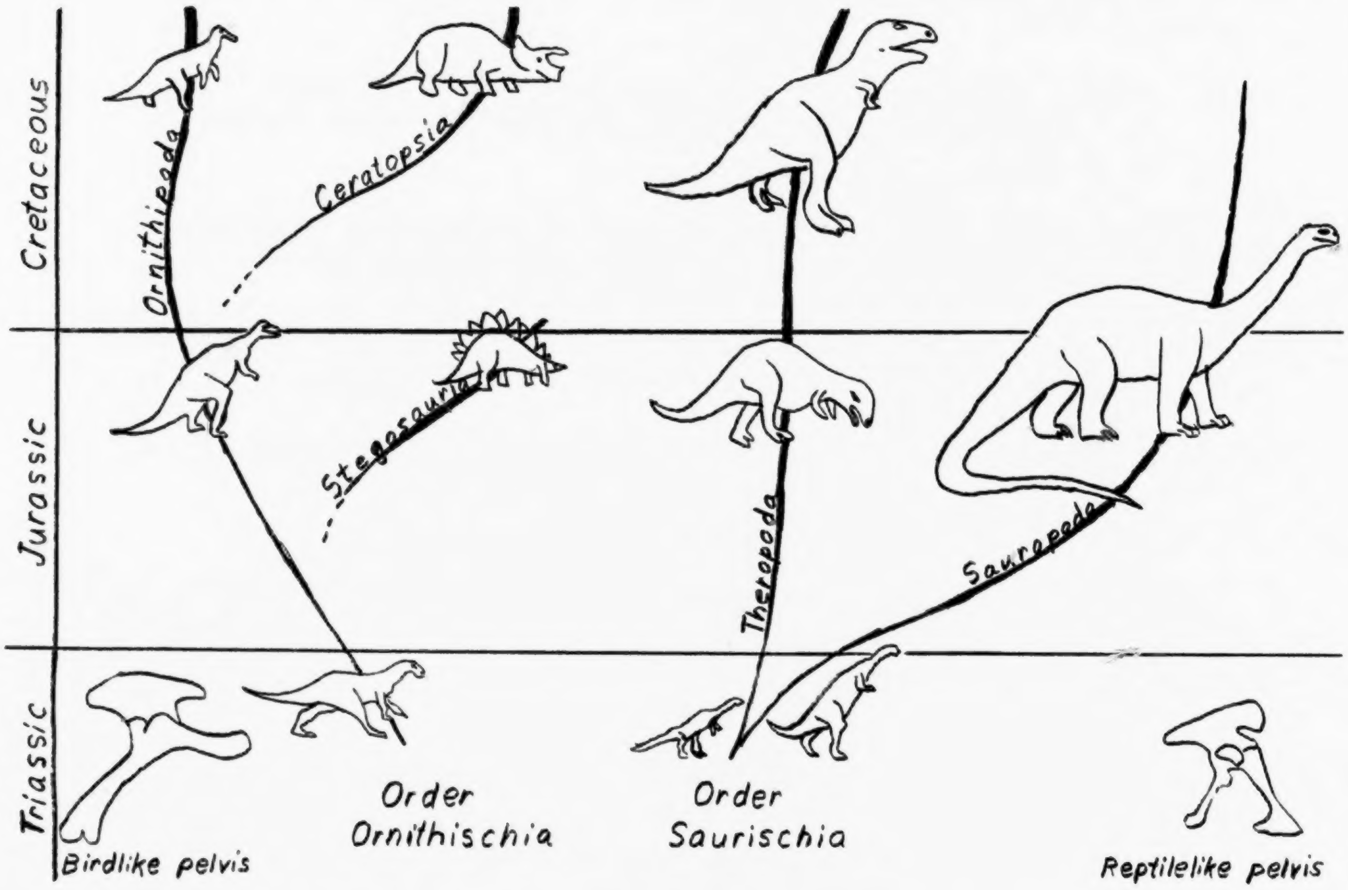
1. Development had begun in the Permian Period.

2. Dinosaurs reached a high stage of development.

a. Sauropods: (Brontosaurus family - "thunder lizard")

1) Apatosaurus - 65 feet long, small brain.
2) Diplodocus - 85 feet long, lighter weight.
3) Brachiosaurus - Heavy, 50 tons.
4) Sauropods were so heavy and bulky that they probably spent most of their time in the swamps or lakes so the water could support a portion of their weight.

b. Armored Dinosaurs included the Stegosaurus.


Cretaceous
Jurassic
Triassic
Ornithopoda
Ceratopsia
Stegosauria
Theropoda
Sauropoda
Order Ornithischia
Order Saurischia
Birdlike pelvis
Reptilelike pelvis

F. The first bird appeared, called Archeopteryx. It had teeth, wings, a tail with feathers, claws on the tips of its wings, and laid eggs.

G. Flying reptiles were also common.

   1. The Pterosaur had a 26-foot wing span.

   2. Flying reptiles were not the relatives of the early birds.

IV. Cretaceous Period Life.

   A. Plant and animal life continued to develop from the Jurassic Period.

      1. Two more forms of dinosaurs appeared.

         a. Horned dinosaurs - Triceratops.

         b. Duck-billed dinosaurs - Trachodon.

      2. Tyrannosaurus - "terrible lizard" developed and flourished. (NOTE: Brontosaurus had become extinct by this time so the two did not live during the same time.)

   a. Tyrannosaurus was about 20-25 feet tall and had a brain about the size of a hen egg.

   b. Became extinct during the last 10-15 million years of the period.

3. Dinosaurs gradually began to become extinct.

   a. The reason is not known.

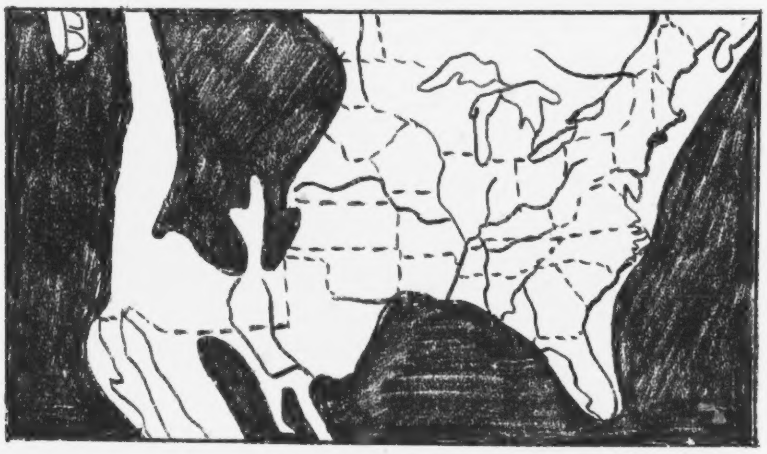
   b. Probably occurred because of elimination of the swamps, due to uplift, as a habitat for the dinosaurs.

4. Birds and mammals increased in both size and number.

5. Marine life consisted of invertebrates, many sharks, bony fish, and the great swimming reptiles. Mesosaur - the greatest "sea serpent" of all times became extinct by the end of the period because of the drain of shallow seas.

6. The first snake developed.

7. Plant life now included the first flowering plants and deciduous trees.



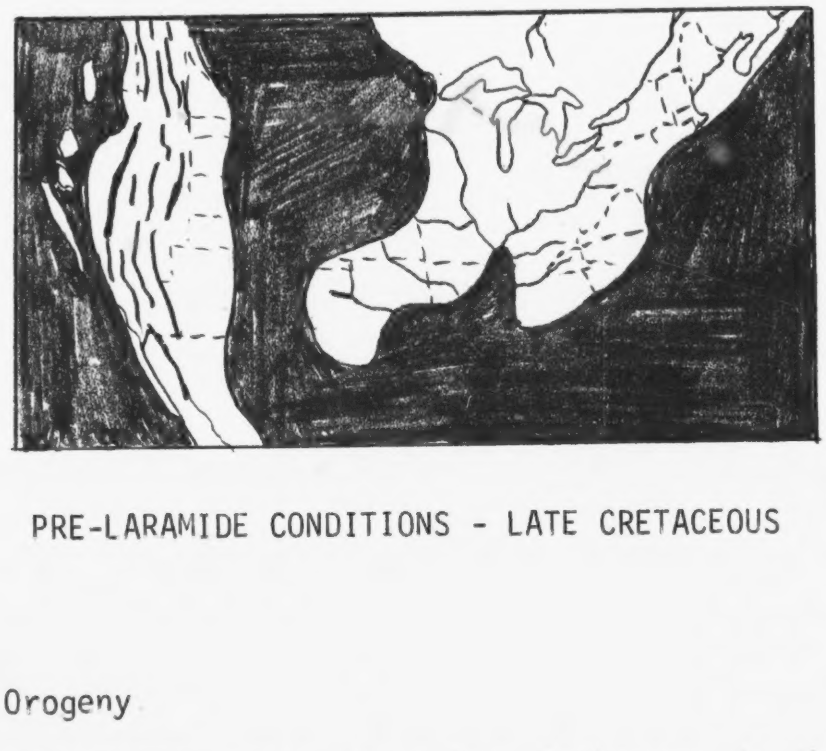
LAND-SEA RELATIONSHIP - LATE JURASSIC

B. Events of the Cretaceous Period.

1. The word cretaceous means chalk. (The period is noted for its chalk deposits. "White Cliffs of Dover".)

2. At the beginning of the period, the Cordilleran Geosyncline was receiving sediments, the majority of which came from the west.

3. The Laramide Orogeny began. (Rocky Mountain Revolution)



PRE-LARAMIDE CONDITIONS - LATE CRETACEOUS

V. The Laramide Orogeny

A. The Laramide Orogeny lasted from late Cretaceous to the Eocene Epoch of the Cenozoic Era.

B. Horizontal forces uplifted and deformed Cretaceous and older strata.

1. Folding and thrust faulting resulting from compressional movements.

a. The Rockies of Colorado and Wyoming are examples of the folding activity.

b. The Lewis Overthrust is one of the best examples of thrust faulting in the world.

2. The Idaho Batholith is the largest igneous body associated with the uplift. (Covers 18,000 square miles.)

3. Exposure of igneous bodies resulted from erosion throughout later geologic time.

C. The uplift resulted in environmental and climatic changes that brought about extinction to many species.

1. The "Age of Dinosaurs" ended with the extinction of all species of the "ruling" reptiles.

2. Some reptiles, many mammals, and birds survived into the Cenozoic Era.

VI. The Cenozoic Era.

The Cenozoic Era covers only 1-2% of geologic time, but the record of events as recorded in the sedimentary rocks is quite clear.

A. The size and shape of the continents was much the same as that of today.

B. Very little submergence occurred except in the Atlantic and Gulf Coast regions. (The present rocks of the Coastal Plains were being formed.)

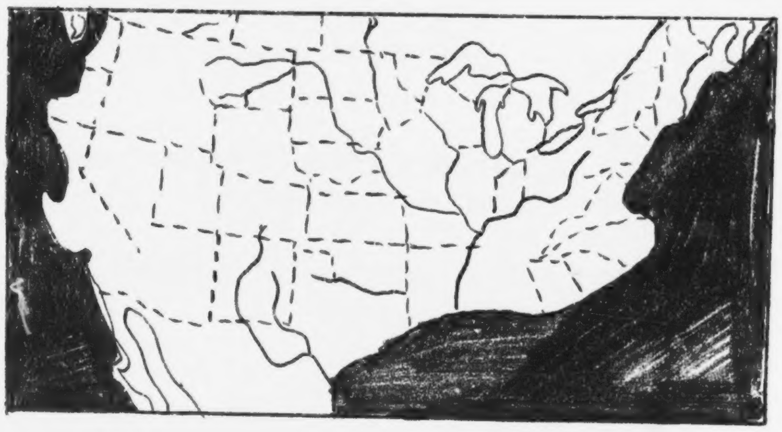
C. The era can be subdivided into two periods:

1. Tertiary - time before glaciation.

2. Quaternary - time during and after glaciation.

VII. The geological history of the Tertiary Period.

A. In the Atlantic and Gulf Coastal Plain, deposits indicate that the area was submerged beneath shallow marine waters, as our continental shelf today, during early Tertiary times.



LAND-SEA RELATIONSHIPS - EOCENE TIME

B. A modern geosyncline lies beneath the northern part of the Gulf of Mexico.

    1. Has been slowly subsiding since the Appalachian Orogeny.

    2. Has received much sediment. (approximately 50-60,000 feet)

C. The Pacific coast saw formation of two mountain ranges and subsidence of an intervening trough.

    1. Coast Ranges.

    2. Sierra-Cascades.

        a. Sierra-Nevada Range is a gigantic fault block (Pleistocene).

        b. Cascade Range is built of volcanic peaks which came into being during the Pliocene. (They also show some evidence of Pleistocene activity.)

            1) Mt. Shasta - hot springs exist near summit today.
            2) Lassen Peak - erupted in 1914-1917.
            3) Crater Lake - collapsed in late Pleistocene.

    3. The intervening trough includes the great valley of California and the Puget-Willamette Valley.

D. The Columbia Lava Plateau was caused by extrusion of basaltic lava from fissures (4-6,000 feet deep) occurring from Miocene to very recent times.

E. Basin and Range Province - fault block mountain and basins.

    1. Faulting during the Miocene (still active in places).

    2. Sediments fill the basins.

F. Colorado Plateau - horizontal layers remain although they are faulted in places.

    1. Deposition occurred during Paleocene and Eocene. (Not entire amount of sediment.)

    2. Uplift occurred at the end of Eocene.

        a. Bryce Canyon.

        b. Zion Canyon.

        c. Grand Canyon.

3. Igneous rocks occur as stocks, laccoliths, and basaltic lava flows.

G. Erosion reduced the Rocky Mountains to a peneplain.

  1. Uplifts occurred periodically during this peneplaination.

  2. Final uplift began during the Miocene-Pliocene and is still going on today.

    a. Superposing of streams.

    b. The Green River has maintained its course through the Unita Mountains cutting Flaming Gorge and Ladore Canyon.

H. Sedimentation occurred in the Great Plains during the Oligocene Epoch.

I. The Black Hills were eroded during the Cenozoic.

J. The Appalachian Mountains had again been reduced to a peneplain by the beginning of the Cenozoic. (Schooley Peneplain)

  1. Uplift of the peneplain caused the present-day Appalachian Mountains.

  2. Uplift also created watergaps because of rejuvenation of the streams.

VIII. Life of the Tertiary Period.

A. Mammals dominated the Tertiary Period life although reptiles (not dinosaurs) were still abundant.

B. Many early Tertiary forms became extinct by the end of the Eocene.

C. More modern forms appeared during the Oligocene and Miocene.

D. By the Pliocene, mammals were modern in form although many did not survive to the present time.

E. The horse developed in Eocene time beginning as a small animal called Eohippus.

  1. Eohippus had 4 toes and was about the size of a fox terrier.

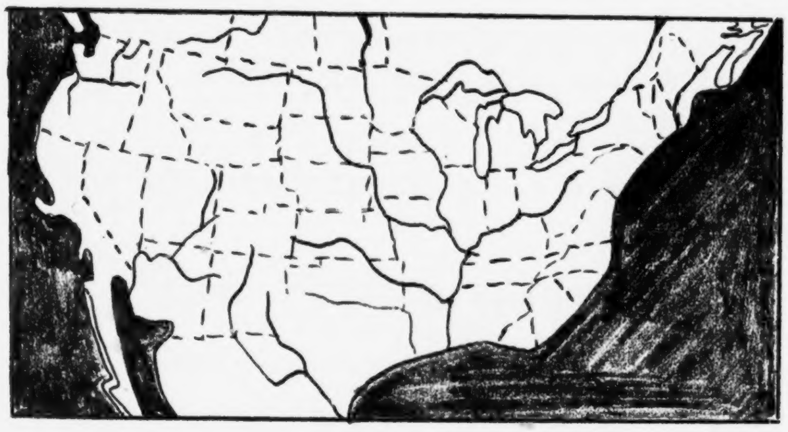
  2. Oligocene saw the development of Mesohippus.

3. Meryhippus developed in Miocene. (3 toes, only one functional)

4. Pliohippus developed in Pliocene.

5. Equus (the present form) developed in Pleistocene.

6. The horse evolved in North America. Equus became extinct in North America before the end of the Pleistocene but managed to migrate through Asia to the old world where it survived to the present.



LAND-SEA RELATIONSHIPS SHOWING ASIAN LANDBRIDGE - MIOCENE TIME

F. Rhinoceroses, camels, and elephants also have evolutionary histories in North America.

   1. Rhinoceroses and camels originated in North America and migrated to other parts of the world.

   2. Elephants developed in Africa and migrated to North America and other areas during the Miocene.

   3. Extinct animal family of North America - Titanotheres.

      a. Brontotherium was a titanothere.

      b. Baluchitherium was a member of the family. Largest land mammal of all times.

         1) Length - about 25 feet.
         2) Height - about 18 feet at the shoulders.

            c. Titanotheres were remotely related to the rhinoceros.

IX. Tertiary plants were ancentors of modern land plants, so plant history is simply a continuation of the evolutionary trend through the Cenezoic toward the present.

X. The Quaternary Period - Pleistocene Epoch.

    A. The chief distinctions of the Pleistocene Epoch are:

        1. It embraced a number of marked climatic fluctuations ranging from cool and moist to warm and dry.

        2. The coming of modern man.

    B. The glacial ages of North America.

        1. Of all the climatic events of the past that have been deduced from geologic evidence, the Great Ice Age is best known.

            a. Effects of the ice age are plainly seen.

            b. Snow fields and glaciers still cover much of the earth.

        2. In North America, the glaciers had two main centers of snow accumulation.

            a. Labrador and Quebec.

            b. Canadian Rockies.

        3. Evidence shows that successive periods of glacial advance were separated by ice-free (interglacial) stages.

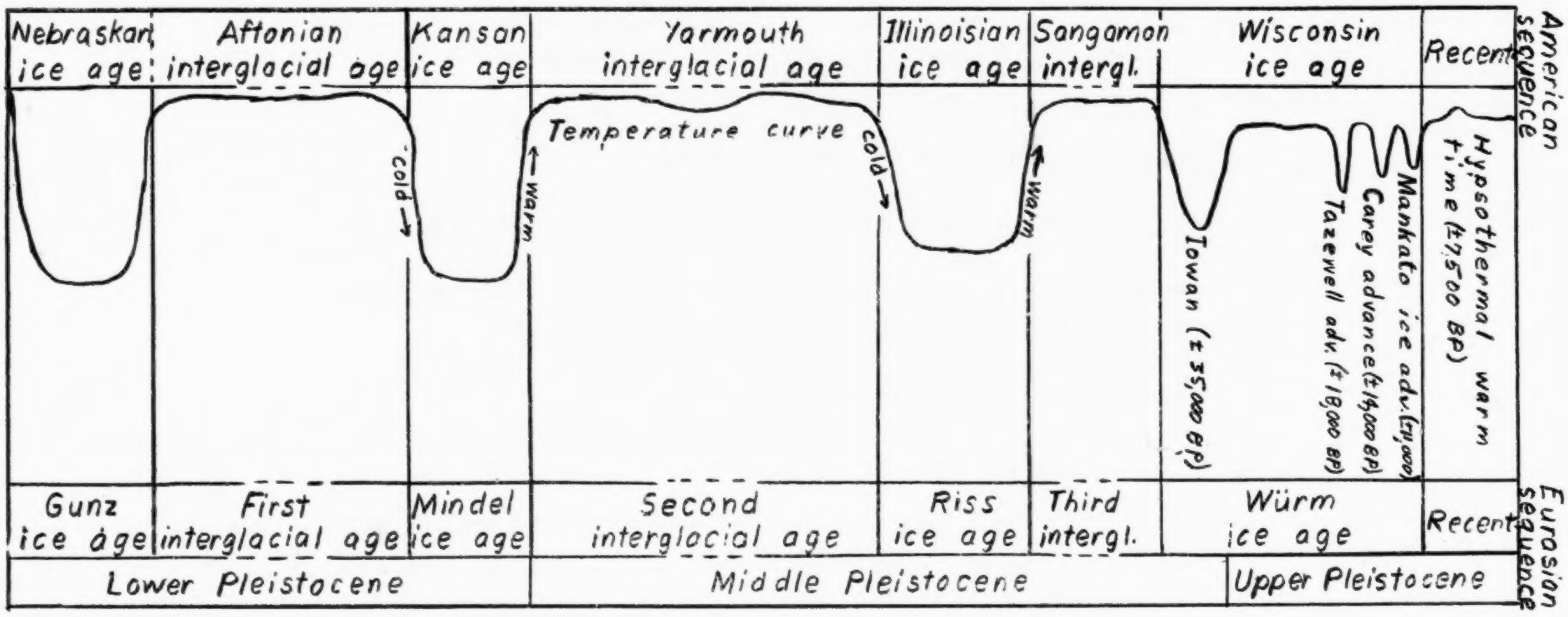
            a. Successive sheets of glacial drift are found piled one upon another.

            b. Ice-free periods are indicated by weathering, soils, wind-blown material, and fossils of "warm-weather" animals.

            c. The Pleistocene Ice Ages have been subdivided into four glacial and three interglacial intervals.

                1) There were minor advances and retreats during these main stages.

2) Time estimates for how long the ice age lasted vary from 1 to 2 million years.



C. Effects of the Ice Age on the land.

1. Areas covered by continental glaciers are subjected to glacial erosion effects and show features characteristic of glacial erosion.

   a. Depression of the crust by ice sheets due to isostasy.

   b. Glaciers planed off the tops of mountains, rounding them and causing a gentle slope on the upstream side of the glacier and a steep slope on the leeward side.

   c. Deposits were left by these continental glaciers.

      1) Moraines mark the margins of the glacier and show successive steps in the retreat.
      2) Till is left where the glacier retreated.
      3) Outwash plains formed as the glacier melted and material was carried away and deposited by the meltwater.
      4) Drumlins and eskers formed.
      5) Erratics (huge rocks) were carried by the glacier from their original position and deposited as the glacier melted.

d. Advance and retreat of the glaciers account for the formation of the Great Lakes.

  1) As the ice sheets melted away, they left a large number of glacial lakes formed in the uneven terrain. (Examples: Present-day Great Lakes left by last glacial advance.)
  2) Other lakes were formed as the glaciers dammed river drainage. (Examples: Lake Agassiz, Lake Souris)
  3) Other lakes appeared as a result of increased rainfall in regions far removed from the glacier. (Examples: Lake Bonneville, Lake Lahontan)

e. Advance of glaciers also forced drainage patterns to shift.

  1) River channels were forced southward as the glacier advanced.
  2) Farthest advance of the glaciers is marked by the position of the Missouri and Ohio Rivers which were pushed southward by the advance.

f. Niagara Falls developed when the glacier rearranged the drainage pattern of the Niagara River and uncovered the escarpment about 10,000 years ago.

g. Alpine glaciation remained active in the Rockies, the Cascades, the Sierra-Nevadas, and the Coast Ranges after the retreat of the main ice sheet.

h. As the glaciers retreated, sea level went up because of excess water. As the glacier advanced, more water was tied up and the sea level went down.

  1) It is estimated that sea level has risen about 350 feet since the last low stage about 40,000 years ago.
  2) Present measurements show that sea level appears to be rising throughout the world.
  3) Calculations suggest that if the present glaciers were to melt, sea level would rise another 250 to 300 feet.

D. Differences in conditions on the earth affected all forms of life to some degree and set the stage for the appearance of modern man.

  1. No radically new or different forms of life appeared in the Pleistocene, but there were notable evolutionary changes involving the creation of new species.

2. Reasons for the changes include migration, mixing, and isolation of species.

    a. Advance of the glaciers forced the life of warm climates south and allowed the cold weather animals to migrate into areas where they previously had not been able to survive. (Examples: Mastodon, mammoth, and musk ox - cold weather allowed them to come south)

    b. Some species could not survive and became extinct.

        1) Camels originated in North America, but the ancestors exist only in South America (llamas), Asia, and Africa (camels).
        2) Horses and zebras originated in North America but migrated to other areas.
        3) Other giant mammals became extinct. (Not thought to be directly attributed to the ice age, but rather to the coming of man.)

XI. Theory of Man's Development.

A. In 1858, Charles Darwin shocked the scientific world as well as the world of the layman with his paper On the Origin of Species.

B. In 1863, Thomas H. Huxley published a book, Man's Place in Nature, which first addressed itself in an orderly way to the problem of man's development.

C. The Descent of Man by Darwin in 1871 was the crowning blow to the dignity of the people of the time.

1. Unfortunately most people jumped to the conclusion that both Darwin and Huxley said that man was descended directly from the living apes.

2. This misconception has held back acceptance of evolutionary theories.

D. According to fundamental evolutionary theory, the evolution of man began as did that of all life, from a common source.

1. Through selective adaptation different species were evolved.

2. Divergence, convergence, parallel descent, and adaptation to change in environment are important in the development of new forms.

E. Although man and apes have a common line of ancestors, the two species finally split and evolved along different lines.

  1. Darwin thought that there was fossil evidence that would undoubtedly connect the two.

  2. This missing link may never be found for the relationship is "cousin to cousin", not "grandparent to grandchild".

F. Ancestors of man are determined and classified according to bone structure similarities.

  1. Man can be classified as a vertebrate, a mammal, and a primate.

    a. Primates include lemurs, tarsiers, monkeys, apes, and man.

    b. Primates possess rather large brains, 5 fingers and 5 toes, fingers and toes with nails, prehensile hands and feet, a flexible arm, a thumb that can be rotated to oppose the other fingers, an eye socket protected by bone, and a total of 32 or 34 teeth.

      1) Suborder Anthropoidea (monkeys, apes, and man).
      2) Superfamily Hominoidea (apes and man).
      3) Family Hominidae.
      4) Generic name - Homo sapiens
         "man" "wise"

  2. Steps essential to production of man are due to genetic changes to gain advantage over the previous form.

    a. The fundamental step was the acquisition of an upright posture.

    b. Development of hands and feet to equal importance in climbing and grasping.

      1) Prehensile hand.
      2) Flexible arm.

    c. Stereoscopic, sharp-focusing eyes with color discrimination.

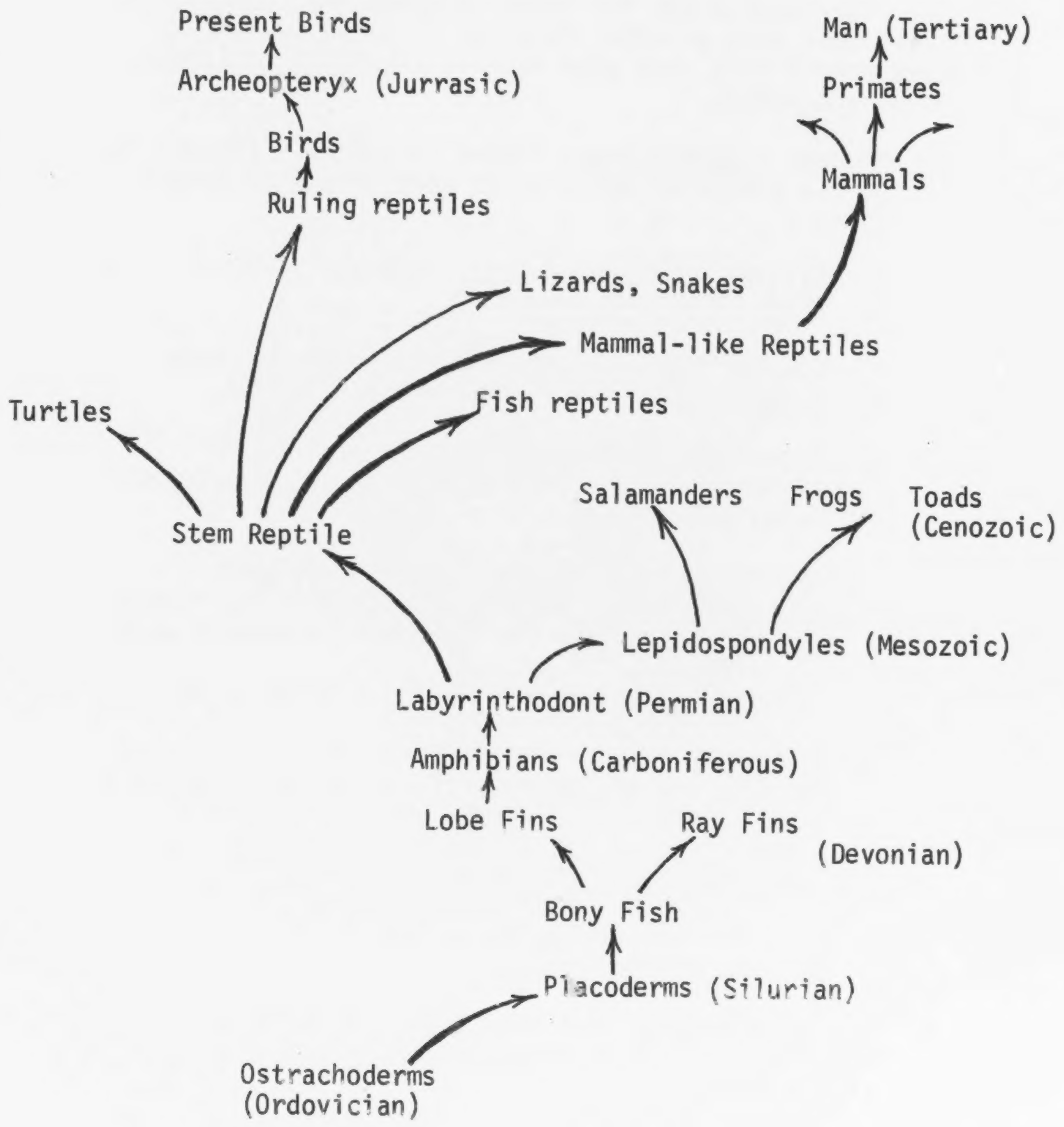
    d. Descent from trees.

      1) Possibly because he was forced out by agressive, tree-living contemporaries.
      2) May have been due to increase in weight.

- e. Development of omnivorous diet thought to be essential to survival of man.
- f. Evolution of the brain.
    - 1) Caused a change in skull shape because of enlargement of the brain.
    - 2) Thought to have been a reasonably fast process.
- g. Changes in food brought about changes in jaw shape, teeth, cheek bones, and brow ridges.
    - 1) Use of tools required less chewing strength.
    - 2) Use of fire for cooking meats.
- h. Social and cultural changes essential to survival.
    - 1) Development of speech. (Also caused development of chin.)
    - 2) Ability of groups to cooperate has great survival value.
    - 3) Parental care of young favored survival.

H. If the principle of organic evolution is valid, man's ancestors date back to first life on earth. (See diagram on following page.)

- 1. Significant evidence for progressive evolution in primates is that members of the primate order appear in the order of their zoological rankings.
    - a. Paleocene - first known primate (Plesiolestes problematicus).
    - b. Oligocene - monkeys and primitive apes appeared.
        - 1) Monkeys have developed into two groups with different characteristics.
            - a) New world monkeys (South America) are more primitive. They have prehensile tails and wide set nostrils. (Example: Spider monkey)
            - b) Old world monkeys (Africa) are more advanced. They lack the prehensile tails and have nostrils set close together. (Example: Ape, chimpanzee)
        - 2) Man belongs to the old world side of the split.
    - c. Miocene - Pliopithecus (ancestor of the gibbon)
      Dryopithecus
      Proconsul (ancestor of chimpanzee and perhaps the ape).


Present Birds
Archeopteryx (Jurrasic)
Birds
Ruling reptiles
Man (Tertiary)
Primates
Mammals
Lizards, Snakes
Mammal-like Reptiles
Turtles
Fish reptiles
Stem Reptile
Salamanders
Frogs
Toads
(Cenozoic)
Lepidospondyles (Mesozoic)
Labyrinthodont (Permian)
Amphibians (Carboniferous)
Lobe Fins
Ray Fins
(Devonian)
Bony Fish
Placoderms (Silurian)
Ostrachoderms
(Ordovician)

2. Man-like fossils are not found in North America as it is thought that primates returned to North America in very recent time, but good fossils are found in Europe, Asia, and Africa.

   a. Miocene - Ramapithecus (found in India). Thought to be the oldest of man's known ancestors in a direct line.

      1) Related to the Proconsul (cousin).
      2) About 14 million years old.

   b. A 9,000,000 year gap separated Ramapithecus from Australopithecus, the first certain humanoid.

      1) Modern man is a product of the ice ages.
      2) Climatic changes affected man and caused adjustments and changes.

         a) Advance and retreat of the ice sheets.
         b) Temperature, sea level, animal life, rivers, and lakes even far from the ice sheets were affected.
         c) Ice Age stages are used for relative dating.

      3) Early man learned to use a variety of tools and the advance of tools is also used for relative time sequences.

         a) Stone Age - Old Stone Age
            Middle Stone Age
            New Stone Age
         b) Age of Metals

   c. Australopithecus (the term means "southern ape") from the early Pleistocene Age was discovered in Africa in 1925.

      1) Stone tools have been found associated.
      2) Small size: weight 60 to 90 pounds.
      3) Definitely bipedal.
      4) Small brain, sloping brow, heavy receding lower jaw, projecting teeth.
      5) Zinjanthropus was a very close relative. Found by Mrs. L. S. B. Leakey in Olduvai Gorge, Tanganyika, and dated as 1,750,000 years old by the potassium-argon method.

D. Paranthropus - A contemporary of Australopithecus, represents an evolutionary dead end.

E. Pithecanthropus - (also referred to as Java Man, Peking Man, Sinanthropus, and generically Homo erectus) lived during early Pleistocene, but apparently later than Australopithecus.

1. Broad skull with rounded back, a low brain case, and flat forehead.
2. Eyebrows were heavy and protruding.
3. Upper jaw large and protruded forward.
4. Lower jaw heavy and lacks a chin.

F. Further steps toward modern man include Solo Man (who became extinct) and Rhodesian Man. (These are intermediate between Pithecanthropus and later forms.)

G. Neanderthal Man (homo sapiens neanderthalensis).

1. True evolutionary position not known, but Neanderthal was not an ancestor of modern man.
2. Native of Europe in the third interglacial interval.
3. Neanderthal was a hunter who used well-formed tipped spears to kill cave bears and hairy mammoths.
4. Used fire and buried his dead.
5. Neanderthal had a squat body, barrel chest, bowed legs, and flat feet.
6. Long, low skull, big jutting brow ridges, flat nose, a protruding muzzle-like mouth and a retreating chin are the facial characteristics of Neanderthal.
7. Brain was larger than that of modern man.

H. Cro-Magnon Man - (homo sapien sapien).

1. Dates to waning stages of last glacial advance (37,000 - 10,000 years ago).
2. Remains of early Cro-Magnon found contemporary with Neanderthal.
3. A complete line of ancestors cannot be traced. There is a "missing link" (actually more than one) but more evidence is found as time passes.
4. Similar in appearance to modern man, only culture separates the Cro-Magnon from modern man.

5. Cro-Magnon was an expert at shaping stone tools and also used bones and antlers to make awls, saws, needles, and weapons.

6. Cro-Magnon used fire and wore clothing.

XII. Man in the new world.

A. Development of primates did not occur in North America and apparently only to the monkey stage (New World Monkeys) in South America.

B. Modern Man migrated from Asia in the late Pleistocene via the Bering Straits area land bridge.

1. These early migrants may not have been ancestors of the Indians.

2. Created a characteristic type of projectile point called the Folsom point.

3. Two invasions of man into North America.

a. 30,000 years ago.

b. 12,000 years ago.

LESSON 32, Introduction

NORTH CAROLINA GEOLOGIC HISTORY

Objective:

To develop a comprehensive picture of the development of North Carolina from Precambrian to the present.

Special References:

Stuckey, J. L. NORTH CAROLINA: ITS GEOLOGY AND MINERAL RESOURCES, (Department of Conservation and Development, Raleigh).
Stuckey, J. L. and Steel, W. G. GEOLOGY AND MINERAL RESOURCES OF NORTH CAROLINA, (Department of Conservation and Development, Raleigh).
Stuckey, J. L. and Conrad, S. G. GEOLOGIC MAP OF NORTH CAROLINA, (Department of Conservation and Development, Raleigh).

LESSON 32

NORTH CAROLINA GEOLOGIC HISTORY

I. History.

A. Precambrian.

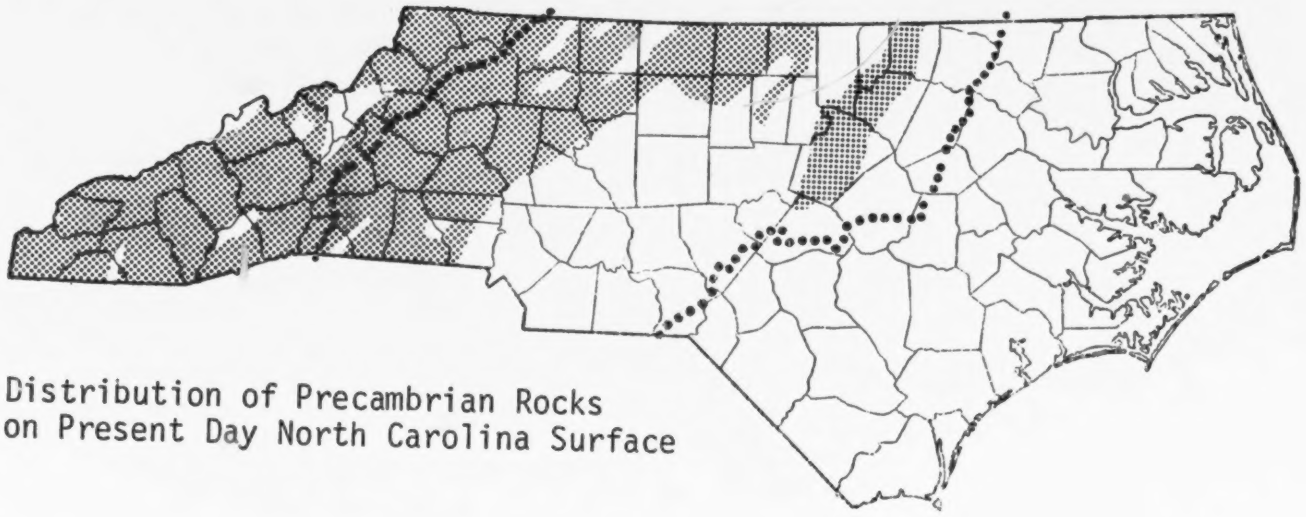
1. During early Precambrian a series of sediments were deposited and metamorphosed by intruding igneous rocks and lava flows.

2. During late Precambrian more volcanic activity took place in a developing geosyncline. These sediments have been metamorphosed and are exposed today in three distinct groups.

   a. Slightly metamorphosed sedimentary rocks including schists, phyllites, slates, quartzites, and marbles.

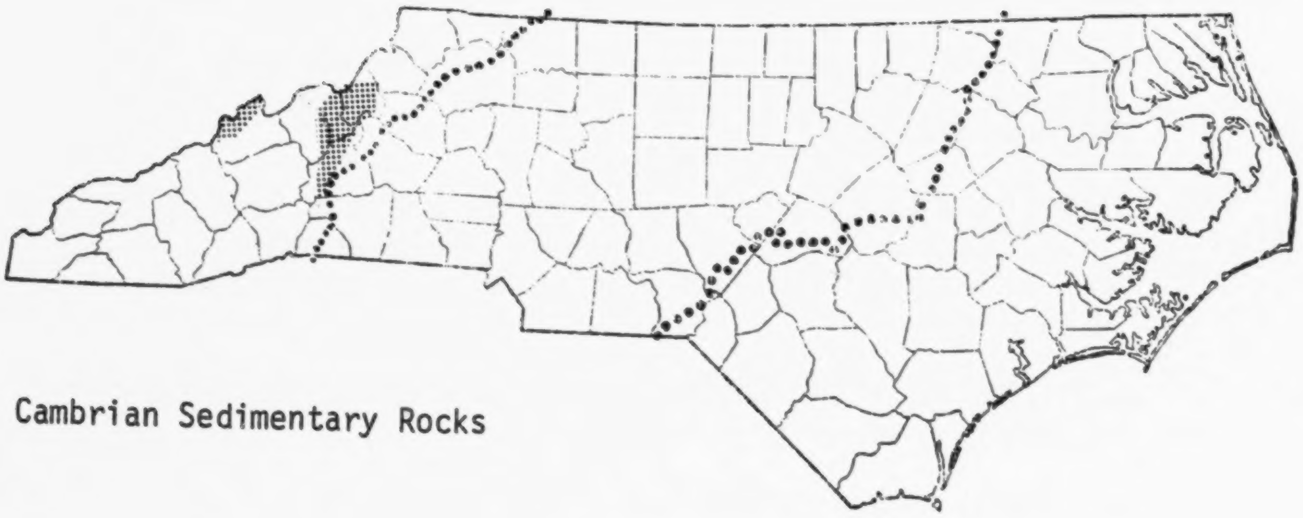
   b. Highly metamorphosed gneisses and schists.

   c. Highly metamorphosed igneous rocks varying from granite to peridotite.



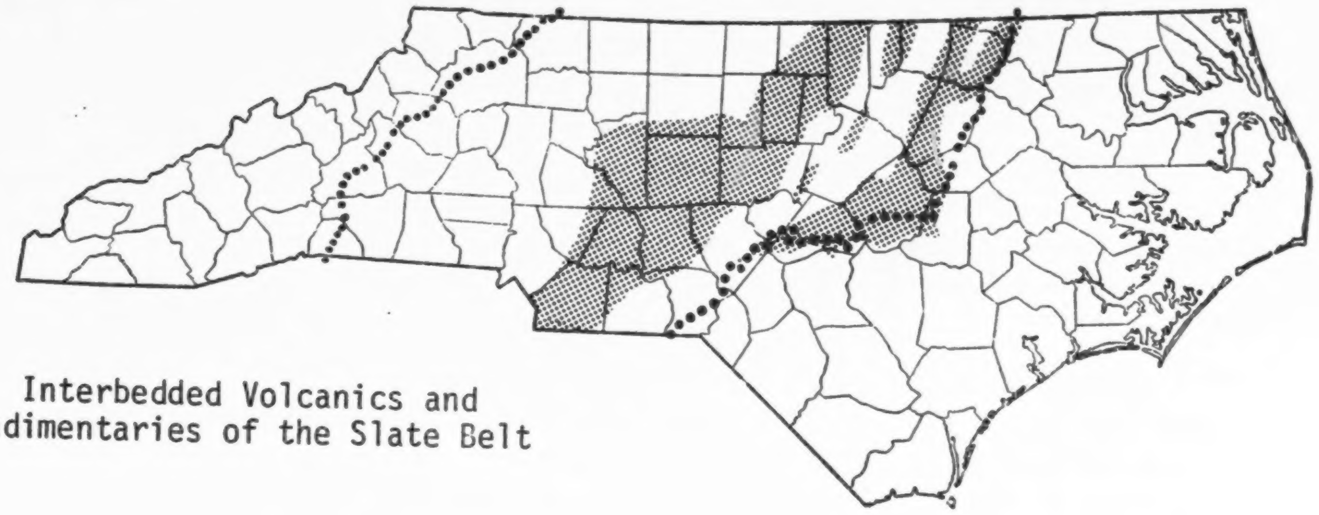
Distribution of Precambrian Rocks
on Present Day North Carolina Surface

B. Cambrian was a period of continuing deposition in the developing geosyncline. The rock formations which are generally accepted as Cambrian occur in the Great Smokies and the Grandfather Mountain area and consist of conglomerates, sandstones, shale, and limestones.



Cambrian Sedimentary Rocks

C. Ordovician time saw the beginnings of instability in the developing geosyncline with the formation of a number of volcanoes. They formed a series of volcanic sediments (sedimentary rock constructed from the debris of eruption) principally shales interlayered with tuffs, breccias, and lava flows. These rocks occur in a belt varying from 15 to 60 miles wide across the piedmont of North Carolina.



Interbedded Volcanics and Sedimentaries of the Slate Belt

1. The volcanic activity was, at least partially, responsible for metamorphism of the Cambrian and Precambrian rock.

2. Continued igneous activity resulted in intrusions of quartz, monzonite, and granites.

3. Hot solutions emplaced pegmatite bodies in the Mitchell, Avery, and Yancey County areas.

4. Taconic Revolution - represented the beginning of mountain building in the Appalachian geosyncline. It is possible that the metamorphic rocks in the northwestern piedmont were changed to some degree as a result of the activity further north.

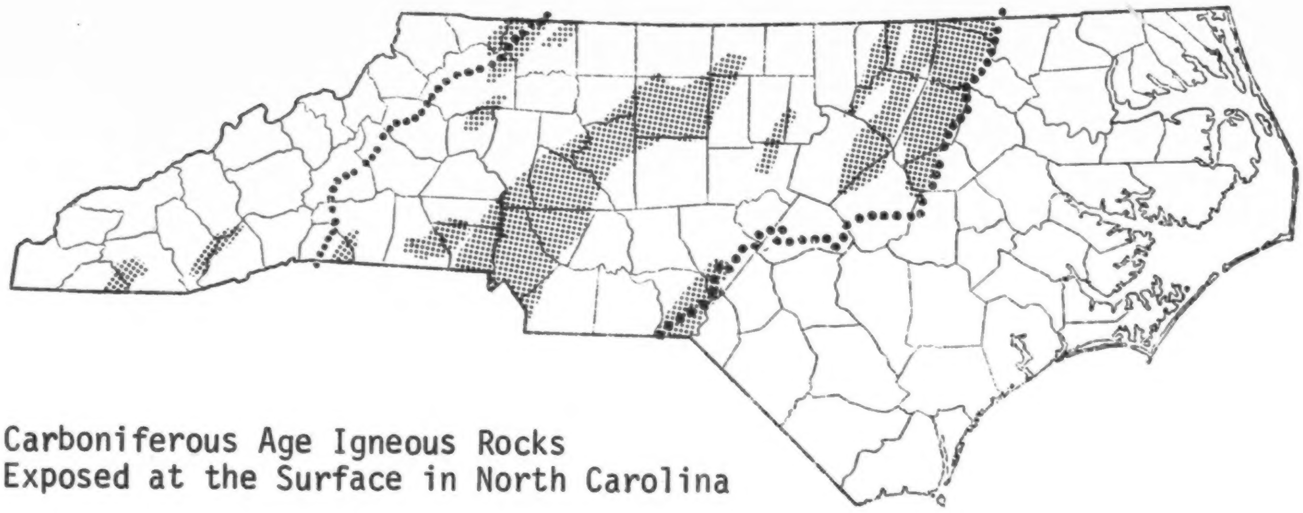
D. Silurian was primarily a period of erosion; however, there were some granite intrusions at various times.

E. Devonian - the beginning of Devonian saw a continuance of the erosion of Silurian time; however, as time progressed igneous activity increased.

1. Granite and quartz monzonites were intruded in the western piedmont.

2. In the slate belt (Ordovician) shales were metamorphosed and converted to slates.

F. Carboniferous (Mississippian, Pennsylvanian) was a prolonged period of erosion with increased igneous activity. The igneous intrusions were principally granites and diorites.



Carboniferous Age Igneous Rocks
Exposed at the Surface in North Carolina

G. Permian - Appalachian Revolution.

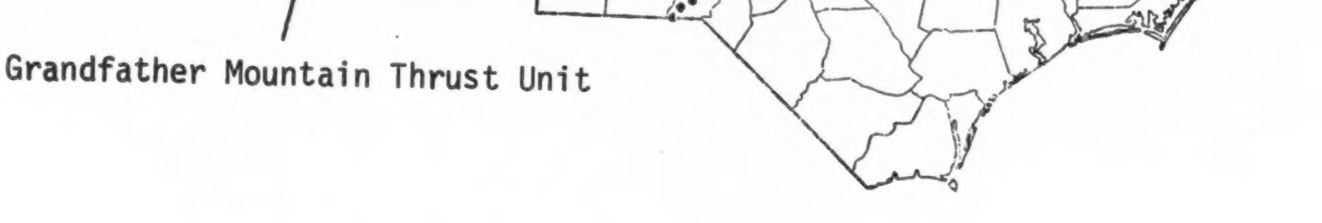
The Appalachian revolution raised the geosyncline and created the Appalachian Mountains. Folding and faulting was extensive to the north and west of North Carolina, reaching a climax in Virginia, Tennessee, and Kentucky where tremendous folds occurred (today's ridge and valley province).

1. In North Carolina there was extensive faulting and uplift along with major thrusts from the southeast to the northwest.

    a. The hot springs window is framed by rocks of the ocoee series in at least four thrust faults and occurs in the western part of Madison County.

    b. The Grandfather Mountain window was formed when Paleozoic rocks were thrust at least 30 miles northwestward over Precambrian and Cambrian rocks.

    c. The thrust faults and fold structure indicate that deforming forces came from the direction of the Piedmont and folded up the sediments of Tennessee and Kentucky against the rocks of the interior.


Hot Springs Thrusts in Smoky Mountains
Grandfather Mountain Thrust Unit

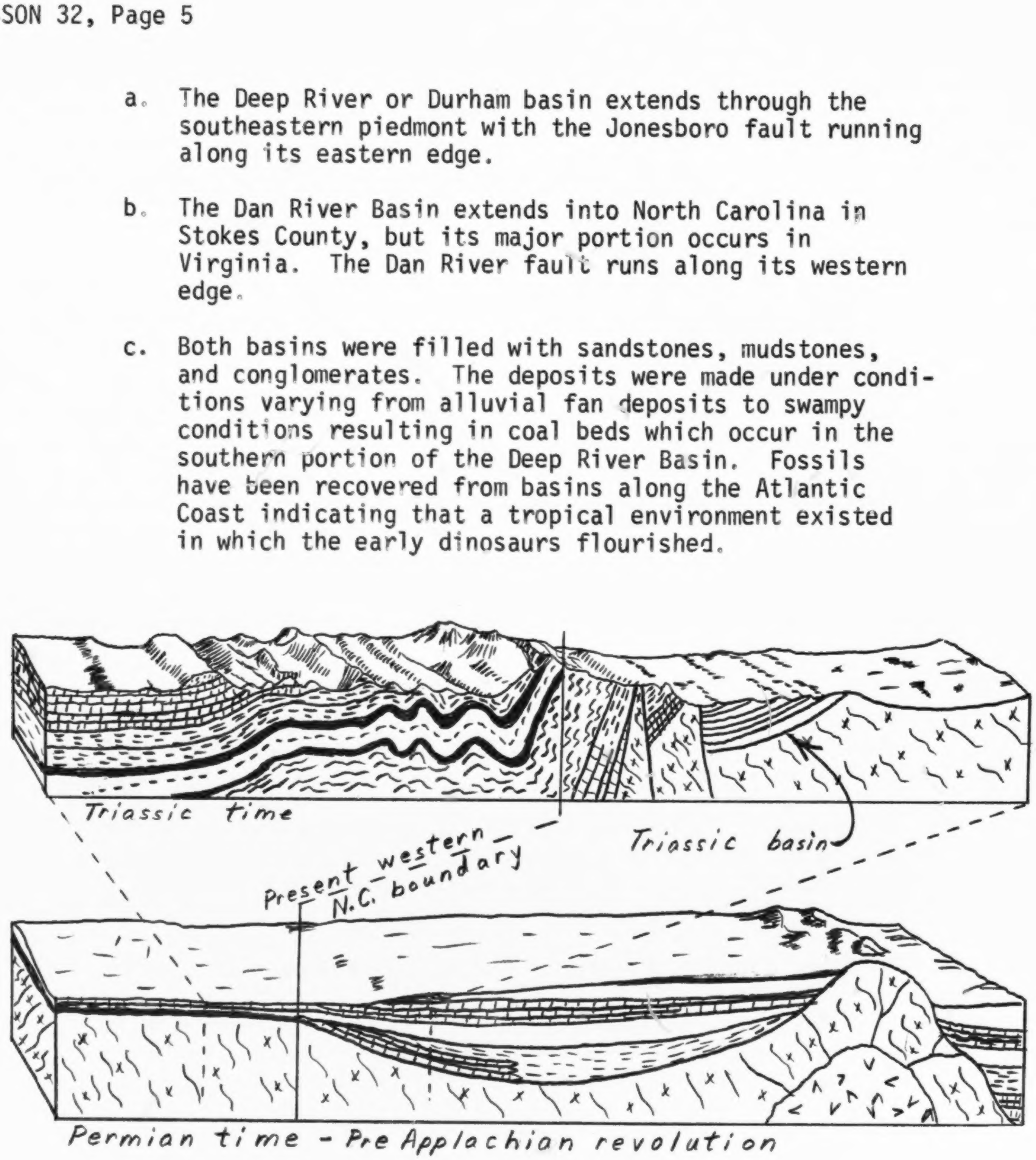
H. Triassic was a prolonged period of destruction as the forces of weathering and erosion worked to level the newly raised Appalachians.

1. During late Triassic faults occurred all along the Piedmont from New Jersey to Georgia. In North Carolina the faulting created two structural basins.

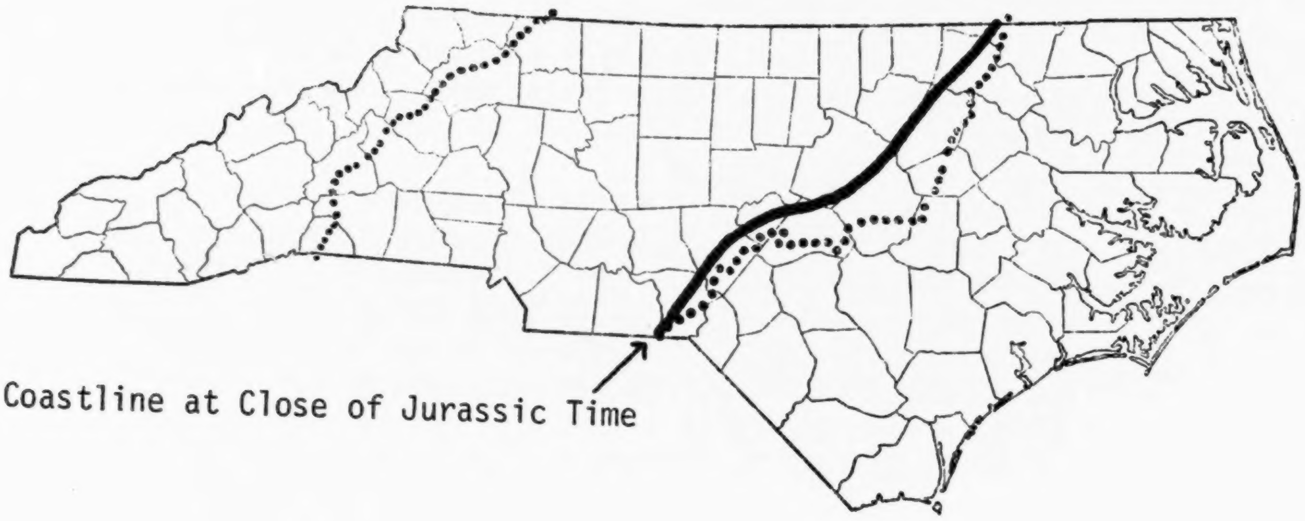
a. The Deep River or Durham basin extends through the southeastern piedmont with the Jonesboro fault running along its eastern edge.

b. The Dan River Basin extends into North Carolina in Stokes County, but its major portion occurs in Virginia. The Dan River fault runs along its western edge.

c. Both basins were filled with sandstones, mudstones, and conglomerates. The deposits were made under conditions varying from alluvial fan deposits to swampy conditions resulting in coal beds which occur in the southern portion of the Deep River Basin. Fossils have been recovered from basins along the Atlantic Coast indicating that a tropical environment existed in which the early dinosaurs flourished.


Triassic time
Triassic basin
Present western N.C. boundary
Permian time - Pre Applachian revolution

I. Jurassic - Weathering and erosion of the mountains in the area of today's Blue Ridge and Piedmont continued with sediments being transported to the present coastal plain. By the close of Jurassic time some 1300 feet of sediment had been deposited in the Cape Hatteras area. The erosion had reduced the surface of the mountains and piedmont to a peneplain surface. At the close of the Jurassic Period, the mountains and piedmont were elevated and the coastal plain depressed, resulting in a renewal of erosion in the western portions and flooding of the eastern portions. The coastline was at least as far west as Candor in Montgomery County.



Coastline at Close of Jurassic Time

J. Cretaceous - during Cretaceous erosion of the uplifted western portion continued, and deposits on today's coastal plain built up.

K. Paleogene - (Paleogene, Eocene, Oligocene) was again a period of erosion in the west and deposition in the east. The sediments built up to a considerable depth, but the present coastal plain remained submerged.

L. Neogene (Miocene, Pliocene, Pleistocene, Recent).

   1. Miocene - deposition continued on the coastal plain. A closed basin developed in Beaufort County, resulting in phosphate deposition. In the west the mountains had been eroded to a second peneplain surface (the Schooley Peneplain) and a second uplift occurred which re-established erosion.

   2. Pliocene - Pleistocene - Recent.

      Erosion of the newly uplifted Schooley Peneplain has dissected the surface forming the present land surface. Continental glaciation evidently did not reach into North Carolina, but the climatic effects were felt as evidenced by the types of flora present today along the crest of the Smokies and Blue Ridge. The coastal plain rose slightly exposing the plain and moving the shoreline to the present location.

II. Topography.

In North Carolina the land can be divided into three segments:

A. The Coastal Plain.

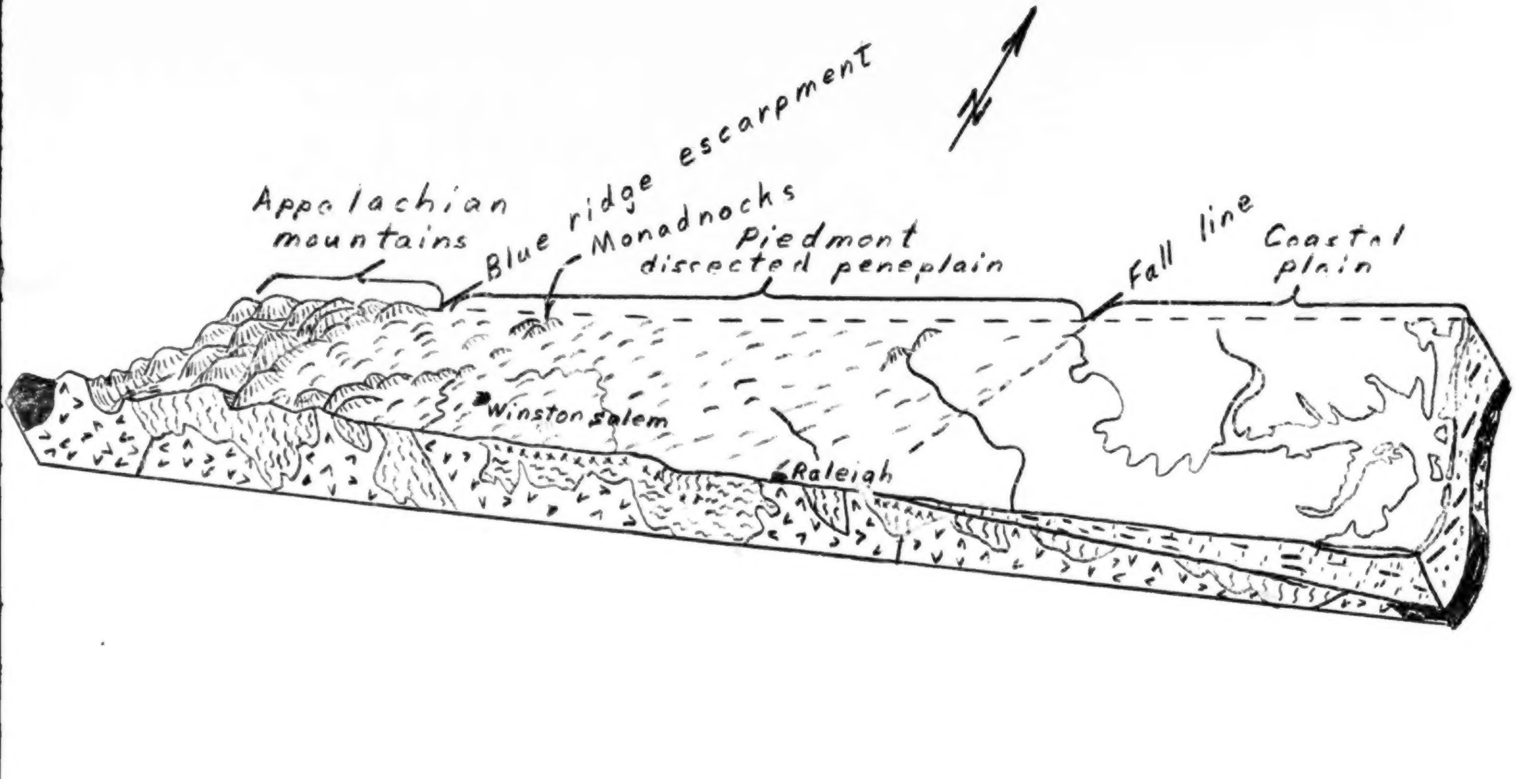
1. Western boundary is marked by the fall line.
2. At one time the plain was elevated considerably resulting in rivers cutting rather deep valleys. Features today indicate some emergence - barrier bars and closed lagoons.

B. The Piedmont.

1. Dissected peneplain surface dotted with monadnocks.
2. Generally dendritic drainage.
3. Western border is the Blue Ridge escarpment thought by some to be caused by erosion.

C. The Mountains.

The Blue Ridge varies from a tangled mass of mountains in the south to a series of rolling hills in the north. The tops of the mountains represent the old Schooley Peneplain surface with the exception of a few monadnocks (Mt. Mitchell, Grandfather Mountain, and the Unaka Range).


N
Blue ridge escarpment
Appalachian mountains
Monadnocks
Piedmont dissected peneplain
Fall line
Coastal plain
Winston Salem
Raleigh